SNAKE RIVER BIRDS OF PREY SPECIAL RESEARCH REPORT

TO THE
SECRETARY
OF THE
INTERIOR

June 1979

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
BOISE DISTRICT
IDAHO

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SECRETARY OF THE INTERIOR

PREPARED BY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
BOISE DISTRICT

JUNE 30, 1979

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SYNOPSIS

A combination of topography, climate, soils, and prey interacts to provide a unique habitat for nesting birds of prey in and around the Snake River Canyon of southwestern Idaho. Vertical canyon cliffs with numerous fractures and cavities provide ideal nesting sites for raptors, and the soils and vegetation on the surrounding desert plateau support abundant populations of prey.

The BLM provided protection to part of the raptor population in 1971 when it established the Snake River Birds of Prey Natural Area, but hunting areas of the raptors and nearly half of the nesting population were not included in the sanctuary. The same lands that supported abundant prey populations were sought for agricultural development under the Desert Land Entry and Carey Acts. To assess the impacts of this potentially conflicting land use, the BLM initiated an integrated team research project in 1975, designed to investigate the ecology of raptors and their prey. The BLM imposed a moratorium on agricultural development within the study area pending research results.

Research has shown that at least 7 general prey groups are important to raptors nesting in the BPSA. Densities of each of the prey are habitat-specific. Townsend ground squirrels are most abundant in winter-fat and grass; jackrabbits prefer sagebrush zones; small rodents are concentrated in the canyon; and reptiles prefer shadscale and rocky areas.

Prey populations varied during the study. Ground squirrel populations declined drastically after a drought in 1977, remained low in 1978, and still have not recovered in 1979. Jackrabbit numbers have undergone more cyclic changes. Rabbit numbers probably peaked in 1971, started to decline in 1972, reached low levels from 1973-75, and returned to average levels in 1976-78. No apparent yearly changes in the populations of pheasants, rodents, passerines, reptiles, or cottontails were detected.

Prairie falcons, the most numerous of the raptor species, feed primarily on Townsend ground squirrels; jackrabbits are the primary prey of golden eagles; and red-tailed hawks feed on a variety of birds, reptiles, and mammals.

Of the three major raptor species, prairie falcons have the largest home ranges and forage farthest from their canyon nests. Prairie falcons have large, elongated home ranges running in a general northeasterly direction up to 25 km from their nests. Their specialized diet, the patchy distribution of their single most important food item, competition from other raptors, and the falcon's characteristic hunting style are probably responsible for the falcon's need to forage over large areas. Golden eagles and red-tailed hawks, in contrast, have smaller ranges near the canyon which they defend.

The density of raptors along the canyon in the BPSA is higher than in any other area reported in the literature, and the diversity of raptors is higher than in any other North American area studied. Up to 646 pairs representing fifteen species, including two classed as sensitive by the BLM and Idaho Fish and Game Department, nest along the Snake River between Walter's Ferry and Hammett.

The distribution of nesting raptors closely corresponds to the distribution of both Townsend ground squirrels and cliffs. Prairie falcons are responsible for most of the variation in total number of nesting pairs. Analysis shows that the abundance of prey on the desert is the most important factor accounting for high raptor densities. Upstream and downstream from the BPSA, where ground squirrel densities decline, the number of raptors (mainly prairie falcons) nesting per unit of cliff area is reduced. Surveys also show that yearly declines in Townsend ground squirrels are associated with a decrease in the number of prairie falcon pairs in the canyon. The canyon alone cannot ensure the continued existence of raptors along the Snake River. Reduction of prey would result in the loss of raptors from the area.

Raptor reproduction was also tied to prey abundance in the BPSA. The number of prairie falcons fledged per pair was directly related to yearly Townsend ground squirrel densities. Mortality of nestling prairie falcons increased when ground squirrel numbers were low. Similarly, reproductive performance of golden eagles declined in response to declines of their major prey, black-tailed jackrabbits. Fewer eagle pairs bred, and fewer nestling eagles survived when rabbit populations were low.

The close relationship between average squirrel densities in the BPSA and yearly prairie falcon reproduction was used to predict the effects of reduced prey densities associated with agricultural development. As little as 15% more agriculture would reduce prairie falcon reproduction to a point where the population could not replace itself even in the best prey years. The long-term effect of agricultural development would probably be a reduction in the carrying capacity of the environment and a reduction in the number of breeding prairie falcon pairs. Some traditional golden eagle nest sites would probably be abandoned, but red-tailed hawk density should not change significantly. Raptors that nest on the ground, particularly the "sensitive" ferruginous hawk, would be highly susceptible to agricultural encroachment.

The loss of breeding pairs of raptors from the area would severely compromise the uniqueness and integrity of the BPSA. To prevent this, further agricultural development should be prevented in an area encompassing the habitat now used by the major raptorial species.

A boundary for the proposed Birds of Prey National Conservation Area should be based on the biological needs of the raptors and their prey. The eastern and western boundaries should encompass the unusually high raptor nesting densities along the Snake River Canyon. The northern boundary should include the actual and estimated prairie falcon home

ranges, and the southern boundary should be based on the distances flown from the river by red-tailed hawks and golden eagles. The present opportunity to protect and manage an area on an ecosystem basis is unique in the history of natural resource conservation.

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PREFACE

The data presented in this report were collected during the first phase of the Snake River Birds of Prey Research Project. The research project was initiated in 1972 to collect information that would 1) define the area necessary to maintain the stability of the raptor populations and 2) provide the basis for a comprehensive management plan.

The first phase of the project, designed to meet the first objective, consisted of an integrated team research effort funded and directed by the USDI Bureau of Land Management (BLM). Studies were conducted by BLM researchers and 12 university contractors. The U.S. Fish and Wildlife Service and the Idaho Department of Fish and Game have provided advice and counsel to the project since its inception.

This research report presents only those data that were used to 1) document the significance of the raptor populations, 2) establish the boundary necessary to protect them, and 3) predict the effects of agricultural development. This report responds to a directive from the Secretary of the Interior. A more comprehensive report on all aspects of the ecological research will be forthcoming. The data collected in this initial phase will also provide the basis for the second phase of research, that will investigate those raptor-habitat and prey-habitat interrelationships needed to develop the management plan.

This report is part of a collection of BLM documents that responds to the directive from the Secretary of the Interior. Other documents to be included in the Secretary's package are the Birds of Prey Environmental Statement, an interim management plan, an economic report, a public information summary report, and draft legislation. These documents should provide the basis for establishment of the Birds of Prey National Conservation Area by amendment to Title VI of the Federal Land Policy and Management Act (FLPMA), as recommended by the BLM.

ACKNOWLEDGEMENTS

The data presented in this report are a result of the efforts of BLM employees, contractors and volunteers. Only those data needed to meet the Secretary of the Interior's directive are presented in this report, and only those contributors whose data were used in this report are listed.

Major Contributors

Data on Townsend ground squirrel density and population dynamics were collected by the Department of Biology, University of Idaho; Dr. Donald Johnson, principal investigator, Graham Smith and Wayne Melquist, research associates (Contract 52500-CT5-1002). Information on other prey species was collected by the Department of Wildlife Science, Utah State University; Dr. Michael Wolfe, principal investigator, Larry Oftedahl and Jon Montan, research associates (Contract 52500-CT5-1003). Lowell Diller of the Department of Biology, University of Idaho collected data on reptiles. Vegetation was sampled by both Boise District BLM employees and Utah State University contract personnel.

Home ranges of the three major raptorial species were studied by the Department of Biology, Western Illinois University; Dr. Thomas Dunstan, principal investigator, James Harper and Ken Phipps, research associates (Contract 52500-CT5-1013).

Data on raptor density, reproduction, and food habits from 1973 to 1978 were collected by Boise District research personnel led by Michael Kochert and Albert Bammann. Supplemental data on raptor food requirements and energetics were provided by the Department of Wildlife Resources, University of Idaho, Steve Peterson, principal investigator, Gayle Sitter, research associate (Contract 52500-CT5-1064); and by Michael W. Collopy of the School of Natural Resources, the University of Michigan. Food habits samples were analysed by BLM employees in addition to Jack Whitman, University of Idaho and Lewis Farley, Idaho State University. Cliff heights were assessed by Drs. Elton B. Bentley and Richard F. Hardyman, Department of Geology, Boise State University (Contract ID-010-PR8-0073).

Compilation and analysis of data were coordinated by Karen Steenhof, BLM Birds of Prey Research Project. Ms. Steenhof wrote the manuscript with the counsel and collaboration of Michael Kochert and Thomas Kucera.

Technical Review Committee

The report was critically reviewed by the following:

Dr. John A. Wiens, Editor, The Auk and Professor, Department of Biology, University of New Mexico.

Dr. John C. Seidensticker, Research Associate, Office of Zoological Research, Smithsonian Institution.

Dr. Mark R. Fuller, Research Biologist, Migratory Bird Habitat Research Laboratory, U.S. Fish and Wildlife Service.

Dr. Richard R. Olendorff, Endangered Species Coordinator, California State Office, U.S. Bureau of Land Management.

Agencies and Institutions

The following agencies and institutions are acknowledged for helping to make the research project a success: Idaho Cooperative Wildlife Research Unit for background data and historical nest locations; the U.S. Fish and Wildlife Service for necessary permits and assistance in several surveys; the Idaho Fish and Game Department for use of laboratory and field camp facilities and for processing permits; the Bureau of Reclamation for computer facilities, printing services, and general assistance from its personnel; the BLM's California Desert Planning Staff for use of computer facilities; Boise State University, Department of Biology for laboratory facilities and the use of study skins; and the College of Idaho for student volunteers.

Individuals

Appreciation is extended to the following individuals who assisted in the project: the E. T. Evans family for their assistance and the use of their ranch as a field camp; Morlan Nelson and William Meiners for their advice throughout the project; Dr. John Lee for treatment of sick and injured birds found during the study; Dr. Bart O'Gara, Montana Cooperative Wildlife Research Unit for providing student interns; John Oakley for assistance during sabbatical leave from MiraCosta Community College.

In addition, the following volunteers, interns, technicians, and YACC employees assisted in the research: Morton Awes, Arn Berglund, Dave Blasedale, Brian Cade, Steve Cherry, Lyell Chittenden, Martin Cobb, Ted Daehnke, Larry Van Daele, Mike Delamore, Mike DeLate, Charles Denny, Janice Diller, Debby Donahue, John Doremus, Dixie Duncan, Dave Evans, Odd Fremming, Anita Garcia, Mike Gerity, Ron Grant, Lonzo Guilliams, Tom Hamer, Dave Holm, Rich Howard, Brad James, Jim Johansen, Al Kimpker, Bob Lanaghan, Rick Lewis, Jeff Marks, John Messick, Fred Minkler, Kathleen Montan, Bob Montoya, Marc Moritsch, Bill Mullins, Al Nicholson, Pat Olmstead, Randy Olson, Ron Olson, Roger Olson, Lisa Pugliese, Vicki Saab, Scott Sawby, Charles Schwartz, Jim Silva, Jean Sitter, Gary Smith, Kelli Stephenson, Robb Stradley, Frank Storts, Bob Tews, Stan Voshell, Martha Wakefield, Jan Wassink, Jack Whitman, Chuck Woodley, Craig Woods, Jill Wyatt, Laurie Young.

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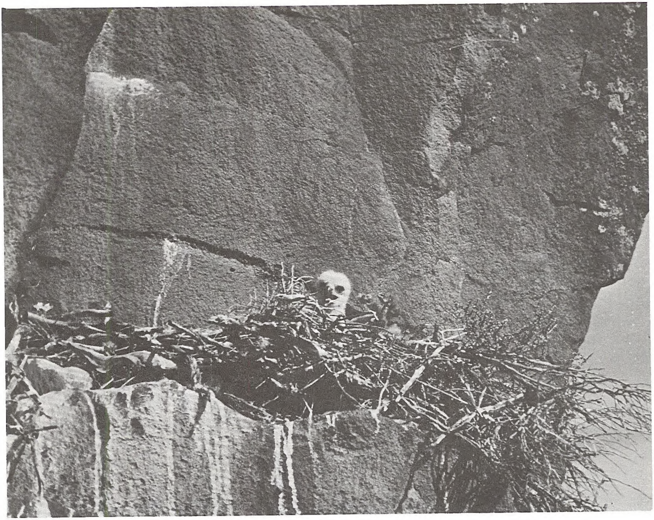
Rick Siegert, Mike Garratt, Dan Hegarty, John Hawkett, and Paul Farrens assisted in computerizing the data.

Clarence Ouellette, Phil Marshall, Kenny Dehlin, Laurie Anderson, Nina Madry, and Dave Hannans of the Idaho BLM State Office Cartographic Branch did the graphic illustrations.

The project could not have been possible without the administrative support of D. Dean Bibles, Boise District Manager; James Gabettas, Assistant Boise District Manager; Alan Tripp, Chief, Division of Resources for the Boise District; Bob Rheiner, Bruneau Resource Area Manager; Joe Arnett and Dan Sedlock, Contracting Officers; and William Mathews, Idaho State Director.

INTRODUCTION



UNIQUENESS OF THE BIRDS OF PREY AREA

In the late 1960's the U.S. Department of the Interior, Bureau of Land Management (BLM), and concerned individuals identified an area in and around the Snake River Canyon south of Boise, Idaho, containing one of the densest nesting populations of birds of prey ever recorded. More than 600 pairs of raptors, representing 15 species, breed and rear their young in the canyon each year. Nowhere else in the country is there as diverse and abundant an assemblage of breeding raptors. The 209 pairs of prairie falcons *(Falco mexicanus)* nesting in this south-western Idaho canyon represent perhaps 5% of the entire population of this endemic species (U.S.D.I. 1979). Two other species that nest in the area, the burrowing owl *(Athene cunicularia)* and the ferruginous hawk *(Buteo regalis)*, are classified as "sensitive" by the BLM and the Idaho Fish and Game Department. In addition to the breeding raptors, 10 species of birds of prey use the area during the fall and winter months. Two of these, the bald eagle *(Haliaeetus leucocephalus)* and the peregrine falcon *(Falco peregrinus)* are classfied as "endangered" by the U.S. Fish and Wildlife Service. Each of the raptor species occupies a slightly different niche in the environment, as shown in Table 1.

Several important factors contribute to the species diversity and abundance of raptors in the area. A unique combination of climate, geology, topography, soils, and numerous other environmental factors makes the area a complete and stable ecosystem where both predators and prey occur in unusually high numbers. Raptor expert Morlan Nelson has stated,

> "The combination of these factors makes this area unique throughout the world as a complete habitat for birds of prey. It is not possible to go in any direction from this area without losing several of the important characteristics that make up this unique situation. The soils change, the geology changes, the climate and water supply change; and in no other area in the Northern Hemisphere or in any other area of the world do these combinations of factors occur to such benefit to the birds of prey."

An understanding of these favorable conditions is fundamental to an appreciation of the area's uniqueness. The two factors most responsible for high raptor nesting densities are an abundance of nest sites in the canyon walls and an abundance of prey in the loess soils in the surrounding plateau.

The Snake River Canyon (Fig. 1) had its origin in volcanic activity two million years ago. Since then, centuries of wind and water erosion have exposed vertical cliffs with literally thousands of small fractures and holes in the canyon walls. In these holes raptors find security and shelter for their nest sites.

The loess soils on the expansive plain above the canyon are vital to both plant and animal life forms, and they are the second physical factor accounting for the unique raptor nesting density. Deposited by winds thousands of years ago, these fertile soils support dense grass

Table 1. General characteristics of birds of prey in the BPSA.

Species	Season of Use	BPSA Abundance	Status	Endemic to North America	Major Prey	Hunting Strategy	Use of Space
Golden Eagle (*Aquila chrysaetos*)	Year-round	Common	*	No	Rabbits	Diurnal, perching, soaring	Territorial
Prairie Falcon (*Falco mexicanus*)	Breeding	Common	*	Yes	Townsend ground squirrels	Diurnal, perching, fast, low flight	Territorial nesting area, Communal foraging area
Red-tailed Hawk (*Buteo jamaicensis*)	Breeding	Common	*	Yes	Small mammals, reptiles	Diurnal, perching, soaring	Territorial
Ferruginous Hawk (*Buteo regalis*)	Breeding	Uncommon	Sensitive	Yes	Small mammals	Diurnal, perching, soaring	Territorial
Swainson's Hawk (*Buteo swainsoni*)	Breeding	Rare	*	No	Insects, small mammals	Diurnal, perching, soaring	Territorial
Marsh Hawk (*Circus cyaneus*)	Year-round	Common	*	No	Reptiles, small mammals	Diurnal, coursing flight, perching	Territorial
American Kestrel (*Falco sparverius*)	Breeding	Common	*	No	Insects, small mammals	Diurnal, perching, hovering	Territorial
Great Horned Owl (*Bubo virginianus*)	Year-round	Common	*	No	Small mammals	Nocturnal, flying, perching	Territorial
Barn Owl (*Tyto alba*)	Year-round	Common	*	No	Small mammals	Nocturnal, flying, perching	Territorial
Screech Owl (*Otus asio*)	Breeding	Uncommon	*	Yes	Small mammals	Nocturnal, flying, perching	Territorial
Long-eared Owl (*Asio otus*)	Year-round	Common	*	No	Small mammals	Nocturnal, flying, perching	Territorial
Burrowing Owl (*Athene cunicularia*)	Breeding	Uncommon	Sensitive	No	Small mammals, insects	Diurnal and crepuscular; perching & hovering	?
Short-eared Owl (*Asio flammeus*)	Year-round	Uncommon	*	No	Small mammals	Nocturnal and crepuscular; coursing flight & perching	?

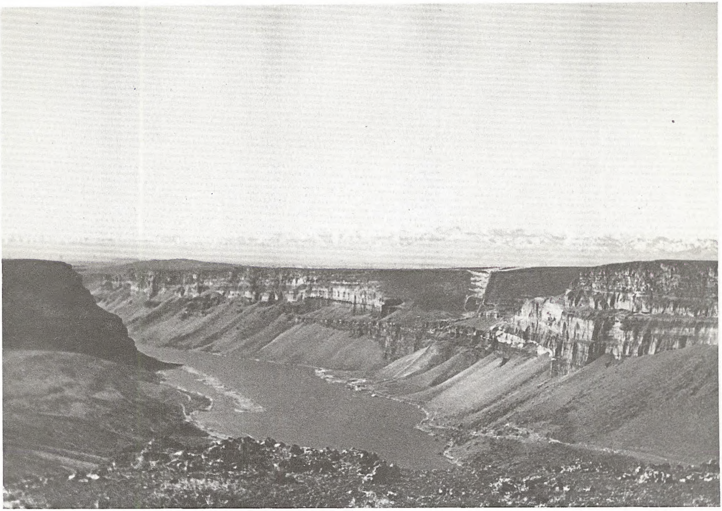
Common Raven *(Corvus corax)*	Year-round	Common	*	No	Small mammals insects	Diurnal, soaring, perching, scavenging	Territorial nesting area, Communal foraging area
Turkey Vulture *(Cathartes aura)*	Breeding	Rare	*	Yes	Carrion	Diurnal soaring	Territorial
Bald Eagle *(Haliaeetus leucocephalus)*	Migration and winter	Uncommon	Endangered	Yes	Fish, small mammals, carrion	Perching	---
Osprey *(Pandion haliaetus)*	Migration	Uncommon	Sensitive	No	Fish	Perching, hovering	---
Peregrine Falcon** *(Falco peregrinus)*	Migration	Rare	Endangered	No	Birds	Perching, fast flight	---
Merlin *(Falco columbarius)*	Migration	Rare	Sensitive	No	Birds	Flying	---
Goshawk *(Accipiter gentilis)*	Migration and winter	Rare	*	No	Birds, mammals	Flying	---
Cooper's Hawk *(Accipiter cooperi)*	Migration and winter	Uncommon	*	Yes	Birds	Flying	---
Sharp-shinned Hawk *(Accipiter striatus)*	Migration and winter	Uncommon	*	No	Birds	Flying	---
American Rough-legged Hawk *(Buteo lagopus)*	Winter	Common	*	No	Small mammals	Perch, hover	---
Gyrfalcon *(Falco rusticolis)*	Winter	Rare	Sensitive	No	Birds, mammals	Flying	---
Snowy Owl *(Nyctea scandiaca)*	Winter	Rare	*	No	Small mammals	Nocturnal, perching	---
Saw-whet Owl *(Aegolius acadicus)*	Undet.	Rare	*	Yes	Insects, small mammals		

* Not presently classified Endangered or Threatened by the U.S. Fish and Wildlife Service or Senstiive by the Idaho Department of Fish and Game.

** Peregrine falcon chicks fostered into prairie falcon nests, as well as migrating.

Fig. 1. Cliffs along the Snake River in the BPSA.

Formed by volcanic activity two million years ago and cut by wind and water erosion, the canyon walls provide ideal nesting sites for birds of prey. Cavities and crevices, typical of vesicular basalt, provide nest sites that are sheltered from the sun and rain, and the massive cliffs allow many pairs to nest in a small area.



CLIFFS ALONG THE SNAKE RIVER IN THE BPSA

and shrub vegetation (Fig. 2). This area supports the largest stand of winterfat *(Cerratoides lanata)* in Idaho. The shrub stands provide essential cover for a variety of wildlife; in addition, small mammals can burrow easily in the medium and fine textured soils, which remain stable in the dry climate.

Townsend ground squirrels *(Spermophilus townsendi)*, an important raptor prey, are one of the more abundant burrowing species. The fertile soils that support big sagebrush *(Artemisia tridentata)*, winterfat, and grass *(Poa* sp. *and Bromus* sp.) also support one of the densest Townsend ground squirrel populations ever recorded. Dense jackrabbit (*Lepus californicus)* populations also inhabit the shrub communities, and several species of lizards and snakes populate the canyon and surrounding plateau. Each species is linked to the soil and vegetation in a slightly different way.

The abundant prey has attracted mammalian as well as avian predators to the area. The same soils that are ideal for ground squirrels are also ideal for badgers *(Taxidea taxus)*, which are more dense in this region than perhaps anywhere else in the world (Messick pers. comm.).

In all, 259 wildlife species (45 mammals, 165 birds, 8 amphibians, 16 reptiles, and 25 fishes) inhabit the region. They interact with abiotic factors to provide a unique habitat for raptors, and together they comprise a complete and stable ecosystem.

ADMINISTRATIVE BACKGROUND

Since the late 1940's, the birds of prey nesting in the Snake River Canyon in southwestern Idaho have gained national prominence and international acclaim (Olendorff and Kochert 1977). On October 12, 1971, 10,819 ha of public land in a 13,052 ha area along the Snake River were withdrawn under Public Land Order 5133. Rogers C. B. Morton, then Secretary of the Interior, joined by Cecil D. Andrus, then Governor of Idaho, dedicated this 53 km stretch of canyon as the Snake River Birds of Prey Natural Area (BPNA) for the protection of raptor nesting and wintering habitat.

During the fall of 1972, the BLM initiated a year-round comprehensive study of all raptors in the BPNA to gather basic information for the management of raptor populations and habitats. Earlier investigations by the U.S. Fish and Wildlife Service and the Idaho Cooperative Research Unit provided considerable background data on eagles, falcons and other large raptors in the area (Hickman 1968, Beecham 1970, Kochert 1972, Ogden 1973, Ogden unpublished data).

After the first year of BLM research, it was determined that the original BPNA encompassed only a portion of the unique nesting population and very little of the foraging area used by the raptors. It was also evident that this foraging area was highly sought for agricultural development under public land disposal laws, specifically the Desert Land Act and the Carey Act. The same soils that were ideal for ground squirrels and badgers were also ideal for growing potatoes, alfalfa, and sugar beets (Fig. 3), and such activities appeared to be incompatible

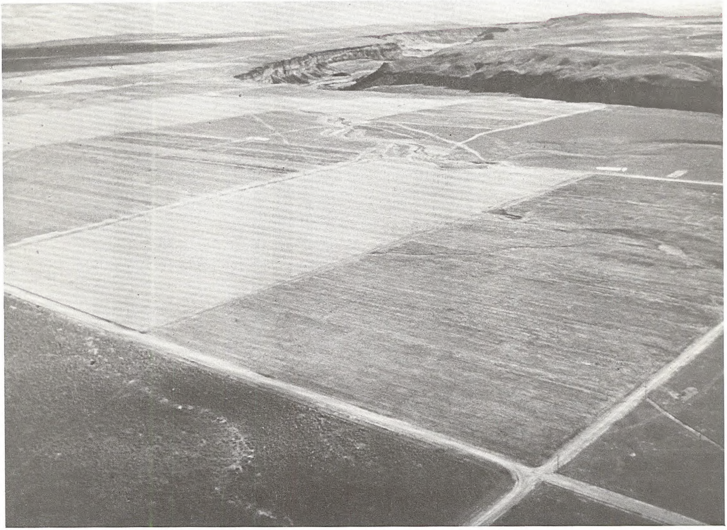
Fig. 2. Dense shrub community in the BPSA.

The fertile soils in the BPSA support dense stands of sagebrush, winterfat, and grasses. The vegetation, in turn, provides food and cover for the raptor's prey. Each prey species has specific habitat affinities: .ground squirrels prefer grass and winterfat cover; jackrabbits prefer sagebrush; and reptiles prefer shadscale. Unfortunately, the cover types where the raptor's major prey species are densest are also those most in demand for agricultural development.

DENSE NATIVE SHRUB COMMUNITY IN THE BPSA

Fig. 3. Typical agricultural development in the BPSA.

Under the Desert Land Entry and Carey Acts, eligible Idaho citizens gain title to government land by paying a fee and proving they can successfully cultivate and irrigate the land. Recent agricultural developments have involved clean farming of large tracts of land, irrigated by sprinkler systems. These modern clean farms are devoid of ditchbanks, fence rows, and other wildlife cover.



TYPICAL AGRICULTURAL DEVELOPMENT IN THE BPSA

with jackrabbits, ground squirrels, and ultimately the raptors. Clearly, more information was needed on the requirements of the raptors and the effects of agriculture before the critical prey populations were lost.

To assess the impacts of this potentially conflicting land use, the BLM initiated a 4 year integrated team research project in 1975 designed to investigate the biology of raptors, their prey and the effects of cultivating their habitat. Since it was essential to keep the land in a natural state during the study, the BLM issued a temporary moratorium on processing Desert Land and Carey Act applications on the land considered vital to raptors and their prey. The area covered by moratorium included an 8 km-wide belt surrounding the BPNA and an additional 64 km of river canyon upstream from the BPNA.

By 1977, research results showed that prairie falcons were hunting several kilometers outside the moratorium area. In response to these findings, Interior Secretary Cecil D. Andrus directed the BLM to increase the area covered by the moratorium by 117,360 ha. The resulting 338,778 ha is now known as the Birds of Prey Study Area (BPSA). At the same time, the Secretary ordered the BLM to consolidate research results by 30 June 1977, in a report which would provide the scientific basis for establishing a permanent boundary for the entire ecosystem based on the long-term spatial requirements of the raptors.

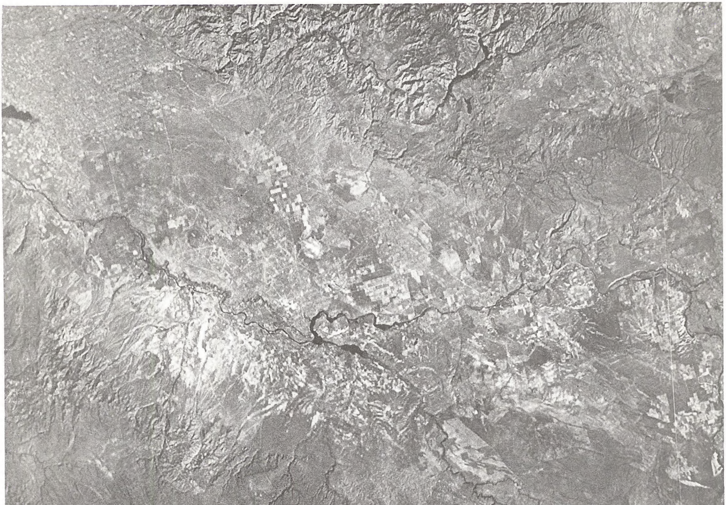
The BLM's basic legislative mandate, the Federal Land Policy and Management Act (FLPMA or Public Law 94-579), directs that especially unique natural systems and processes on public lands be preserved. The BLM has recommended to the Secretary of the Interior that this entire ecosystem be established as a National Conservation Area through amendment to Title VI of FLPMA.

The first step in the logical order of preserving an ecosystem or establishing an ecological preserve is to define the limits of the system and the area required to maintain its integrity. The second step is to define the interactions and requirements of that system and develop a comprehensive management plan accordingly. This phase of the Birds of Prey Research Project has accomplished the first step and this report responds to the Secretary's directive by utilizing the research data to:

1) Establish the uniqueness of the area;
2) Ascertain the amount of space and type of habitat required by the major nesting raptor species to insure long-term stability of their populations;
3) Determine the effects of agricultural encroachment on the long-term stability of the raptor populations; and
4) Recommend a boundary for the area to be proposed as a National Conservation Area.

Only the data and analyses necessary to meet the objectives of this Special Research Report to the Secretary of the Interior are presented herein.

THE ENVIRONMENT



LOCATION

Research was conducted along the Snake River Canyon and on the surrounding desert plateau of Ada, Canyon, Elmore, Owyhee, and Gooding Counties, Idaho (Fig. 4). Most investigations occurred within the 338,778 ha Birds of Prey Study Area (BPSA); supplemental research was conducted in a Comparison Area immediately upstream (east) and downstream (west) from the BPSA. In 1973 and 1974 intensive research focused on the 12,950 ha Birds of Prey Natural Area (BPNA) within the BPSA (Fig. 4), but studies covered the entire BPSA from 1975-78.

The nearest large cities to the BPSA are Boise (est. pop. 150,000) and Mountain Home (est. pop. 10,000), Idaho. The northwestern edge of the BPSA is located 56 km from Boise. Although three major highways cut through the BPSA, access is generally limited within the study area.

CLIMATE AND WEATHER

The BPSA is located in an Upper Sonoran life zone, characterized by shrub-steppe vegetation. The climate is strongly influenced by the precipitation shadow of the Oregon Coast Range and the Cascade Mountains. Annual precipitation averages 20 cm, summers are hot and dry, and winters are mild. Average monthly temperatures and precipitation during the 1974-78 breeding seasons are presented in Table 2. A severe drought occurred between fall 1976 and spring 1977; the amount of rainfall from November to April in 1976-77 was the lowest ever recorded at the Mountain Home weather station. Moderate droughts, however, are not uncommon, occurring approximately every 20 years since the turn of the century (Fig. 5).

TOPOGRAPHY

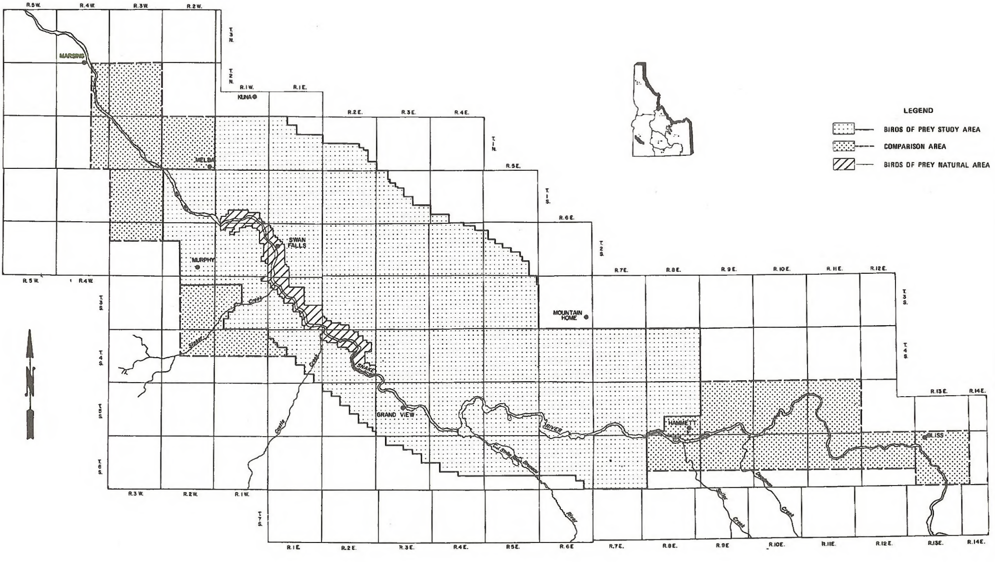
The principal physiographic feature of the BPSA is the Snake River Canyon. The canyon and side draws are comprised of basalt overlying softer sedimentary deposits. Cliffs and canyon walls range in height from 2 to 125 m, with the river cutting as much as 250 m below the surrounding terrain. The elevation of the canyon near Swan Falls, where the canyon is deepest, ranges from 700 m above sea level near the floor to 920 m above sea level at the rim.

Topography above the canyon is generally flat or slightly rolling. A few predominant volcanic features, such as isolated cinder cones and basaltic buttes, dot the otherwise flat landscape north of the river, while lands south of the river are characterized by rolling topography and eroded "badlands."

The amount of cliff area is of prime importance to the birds of prey that nest in the BPSA. To assess the amount of cliff in the BPSA and Comparison Area, the Snake River Canyon was divided into 29 river units of 10 km each (Fig. 6). River units originated at the point where the BPNA western boundary crossed the Snake River. Downstream and upstream from that point, river units were measured along the center of the river to the upstream and downstream ends of the Comparison Area. Five large side canyons included as separate river units were not exactly 10 km in length.

Fig. 4. Location of the Birds of Prey Study Area (BPSA) and Comparison Area.

Research was conducted in 6 counties of southwestern Idaho. Most work was in the official BPSA, but supplemental data were collected in an Upstream Comparison Area and Downstream Comparison Area. Mountain Home and Boise are the nearest large cities.



LOCATION OF THE BIRDS OF PREY STUDY AREA (BPSA) AND COMPARISON AREA

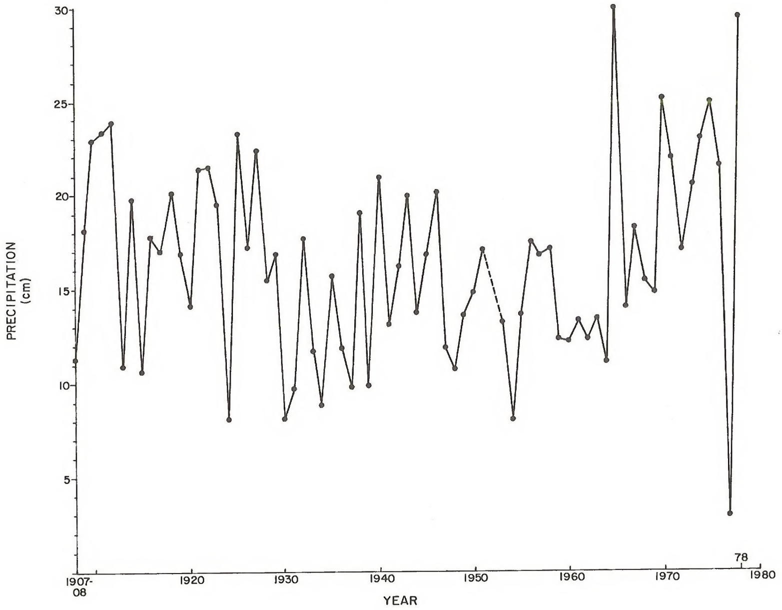
Table 2. Average monthly temperatures (^{o}C) and precipitation (cm) in the BPSA, during the raptor breeding season, January through July 1974-78*.

	Jan.	Feb.	Mar.	April	May	June	July
			Temperatures				
1974	-1.72	3.22	6.22	10.17	14.00	22.39	23.67
1975	-2.22	2.33	5.50	7.45	13.89	18.67	25.84
1976	-0.11	1.33	3.17	9.06	15.72	17.67	23.61
1977	-5.39	2.00	5.11	13.22	12.78	22.61	23.39
1978	2.94	3.39	9.28	10.56	13.67	19.06	23.28
			Precipitation				
1974	2.11	0.79	4.24	1.04	0.41	0.86	0.56
1975	1.35	2.74	2.59	2.72	0.89	1.04	2.67
1976	2.39	2.49	1.32	2.79	0.66	2.69	2.16
1977	1.02	0.69	0.79	0.51	3.66	1.29	2.06
1978	4.06	3.51	2.18	5.00	0.76	1.29	1.50

* Data are from the Bruneau, Grandview 2W, Kuna 2NNE, Mountain Home 3S, and the Swan Falls Powerhouse weather stations.

Fig. 5. Total precipitation (cm) from November to April at Mountain Home, Idaho, 1907-1978.

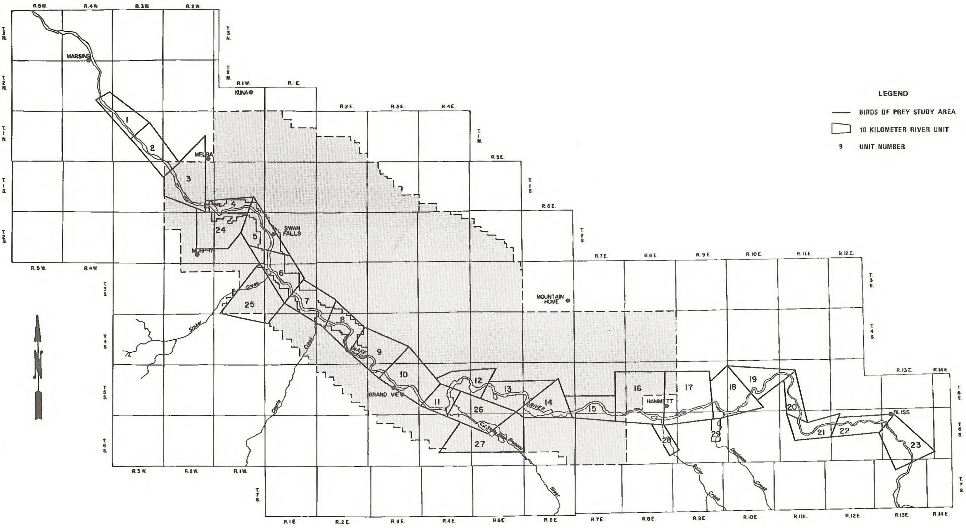
Precipitation from November to April is critical for the growth of annual grasses and indirectly for the reproduction of Townsend ground squirrels. In 1976-77, precipitation during that period was the lowest ever recorded at Mountain Home. Less severe droughts have been common in the region in the last 70 years. Dashed lines indicate years for which no data were available.



TOTAL PRECIPITATION (cm) FROM NOVEMBER THROUGH APRIL AT MOUNTAIN HOME, IDAHO 1907–1978

Fig. 6. 10 km river units along the Snake River, BPSA and Comparison Area.

The canyon was divided into units of 10 km in length for the purposes of analyzing the distribution of cliff, the distribution of raptors, and the relationships between them.



10 KM RIVER UNITS ALONG THE SNAKE RIVER, BPSA AND COMPARISON AREA

Both height of free fall cliff face and height of cliff base above the river were obtained through aerial photo interpretation using standard parallax methods (Ray 1960, Allum 1975, Avery 1977). Some heights were obtained in the field using clinometers and direct measurements to supplement and verify photo interpretation results. Cliff heights were grouped into five arbitrary categories: Cat. I, < 7.6 m; Cat. II, 7.6 - 15.1 m; Cat. III, 15.1 - 30.6 m; Cat. IV, 30.6 - 60.9 m; Cat. V, 60.9 - 121.2 m. Stretches of cliff where the height category did not change were identified as "segments." Segments were plotted on USGS 1:24,000 scale maps and the linear distance of each was calculated. The total linear distance of all segments of a category within each river unit was multiplied by the midpoint of that category (e.g. 3.8 m for Category I) to give an estimate of total cliff area (m^2) for each river unit.

The amount of cliff area in the BPSA and Comparison Area ranged from 41,091 to 989,957 m^2 per 10 km river unit (Table 3). The westernmost river units, near Givens Hot Springs, have cliffs on only the north side of the river. Cliffs appear on both sides of the river upstream from the Walter's Ferry Bridge and reach their greatest height and total area around Swan Falls (Fig. 7). Unit 5 near Swan Falls has 7,625 linear meters of cliff greater than 60 m high (Table 3).

Cliff area decreases upstream from Sinker Creek, with cliffs occurring only on the north side near Grand View (Units 9 and 10). East of Hammett, cliff area is comparable to that in the westernmost portion of the BPSA (Fig. 7), but the amount of cliff increases again at the extreme eastern part of the Comparison Area, near Bliss, where most of the cliff is on the north side.

SOILS

Several soil types, each supporting specific vegetative associations, occur in the BPSA. There is a sharp distinction between soils on the north side of the river and those on the south side. The predominant soils on the north are typified by deep, well-drained silt, silt loams, and silty clay loams formed by loess deposits. Shallow loess soils over basalt flows occur in the central part of the area on the north side. In contrast, the soils south of the river are typified by alluvial deposits of consolidated sand, gravel, and silt, in addition to eroded badlands. Deep loams occur on some plateaus south of the river.

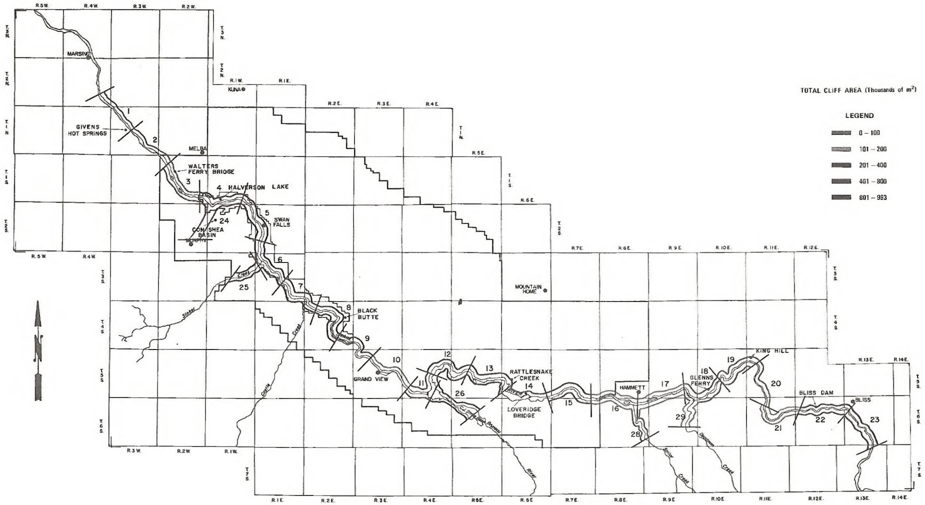
The deep, well-drained silts, silty clay loams, and silt loams on the north side now support sagebrush and winterfat stands, but their characteristics make them highly suitable for agricultural development. Shadscale and greasewood grow on less desirable soils such as thin loess-covered basalt, mixed alluvium, loess-covered badlands (silt hills), or volcanic ash and rubblelands.

VEGETATION

Vegetation within the BPSA is characteristic of a shrub-steppe community in an Upper Sonoran life zone. Homogeneous vegetation stands in the BPSA were identified from color aerial photographs (scale 1:31,680). From spring 1977 through summer 1978, at least one site within each of

Fig. 7. Distribution of cliff heights along the Snake River Canyon, Idaho.

Cliff area in the BPSA is greatest near Swan Falls. The westernmost river units, near Givens Hot Springs, have cliffs on the north side only, while cliffs occur on boths sides of the river from Walter's Ferry Bridge to Black Butte. East of Hammett the amount of cliff area is similar to that in the westernmost portion of the BPSA. Although the figure shows relatively high cliff area on both sides of the river near Bliss, almost all the cliff in Units 21, 22, and 23 is on the north side.



OISTRIBUTION OF CLIFF HEIGHTS ALONG THE SNAKE RIVER CANYON, IDAHO

Table 3. Linear distance (m) of each cliff height category and total cliff area (m^2) for each river unit.

River Unit	CAT. I 0-7.6m (3.8)*	CAT. II 7.6-15.1m (11.4)*	CAT. III 15.1-30.6m (22.9)*	CAT. IV 30.6-60.9m (45.8)*	CAT. V 60.9-121.2m (91.0)*	Total m^2
01	4,310	8,120	2,375	0	0	163,334
02	1,648	5,005	2,479	0	0	120,089
03	7,013	2,684	1,739	427	0	116,627
04	9,799	8,422	7,956	1,525	1,955	563,189
05	2,511	4,965	4,179	2,931	7,625	989,957
06	19,444	8,525	4,281	6,599	2,529	801,480
07	13,027	8,183	1,965	0	365	221,002
08	10,881	7,270	5,116	183	0	249,764
09	6,686	12,717	3,905	0	0	259,805
10	15,460	5,794	0	0	0	124,800
11	4,529	5,287	0	244	0	88,657
12	8,068	5,793	10,216	1,599	0	403,879
13	11,295	3,425	12,898	6,032	0	653,596
14	10,401	1,402	332	0	0	63,109
15	11,474	11,962	1,782	1,754	0	301,109
16	15,696	5,084	1,984	0	0	163,036
17	20,485	8,331	549	0	0	185,389
18	5,497	1,282	0	122	0	41,091
19	2,728	2,848	0	0	0	42,834
20	990	60	1,550	1,192	0	94,535
21	0	8,561	1,759	0	0	137,877
22	683	4,068	4,977	3,415	0	319,351
23	0	6,403	7,623	9,428	304	707,027
24	3,446	7,199	1,754	0	0	135,330
25	5,860	15,012	4,608	0	0	298,928
26	310	3,471	7,561	0	0	213,894
27	0	0	0	0	0	0
28	11,388	380	600	0	0	61,346
29	395	1,856	976	1,341	0	106,428

* Numbers in parentheses represent the midpoint of each cliff height category in meters.

the stands was inventoried by line transects and ocular estimates (BLM Manual 4412.11a; U.S.D.A. 1976). At each site, species composition, percent of each species in the total vegetative cover and percent bare ground were recorded. Boundaries between vegetation stands were verified on the ground, refined, transferred to 7.5 minute topographic maps and digitized (Roseman 1978) for computer analysis. Vegetational data were compiled and analyzed using Comarc Planning Information System (COMPIS) programs on a Data General 330 Eclipse Computer.

Nineteen distinct cover types (Table 4) were identified on the basis of physiognomic differences and preliminary analyses of prey-vegetation relationships. Each homogeneous stand was classified in an appropriate type according to its percent vegetative composition.

Big sagebrush associations are the most common cover types, comprising more than 37% of the BPSA (Table 5). Grass associations are the second most common types in the BPSA, and shadscale types rank third. Almost 19% of the BPSA is cultivated; 12% is under modern clean agricultural techniques (sprinkler irrigation), and 7% is under older methods (gravity irrigation).

Shadscale and greasewood cover types occur more frequently south of the river, while big sagebrush occurs predominantly north of the river (Fig. 8). Sagebrush and grass associations dominate the westernmost portion of the BPSA, shadscale associations are more common in the central parts, and sagebrush again dominates in the east.

LAND USE

The major land uses within the BPSA are agricultural development, grazing, and recreation. Minor land uses include mineral development and military maneuvers. The Snake River has been considered the "lifeline" of Idaho because its water supports most of the agriculture, industry, and municipalities in the state. Most of these activites occur within an 80 km belt along the river and its major tributaries.

About 94,527 ha of the 338,778 ha BPSA is in private ownership. Approximately 64,548 ha (68 percent) of these private lands are presently being farmed for potatoes, sugar beets, beans, corn, grain, and alfalfa. The area currently farmed represents 19% of the entire BPSA (Table 4), but the area with potential for agricultural development is much greater. Most of the currently farmed areas in the BPSA are south of Mountain Home.

The most extensive use of the public and much of the private land within the BPSA is livestock grazing. The public lands are used primarily as spring, fall, and winter range for cattle. Sixty-six grazing permittees presently utilize nearly all of the public lands in the BPSA to maintain yearlong cow-calf or sheep operations.

The BPSA is a major scenic, geologic, and wildlife attraction in southwestern Idaho. The Snake River plateau and canyon are rich in

Table 4. Criteria for distinguishing cover types in the BPSA

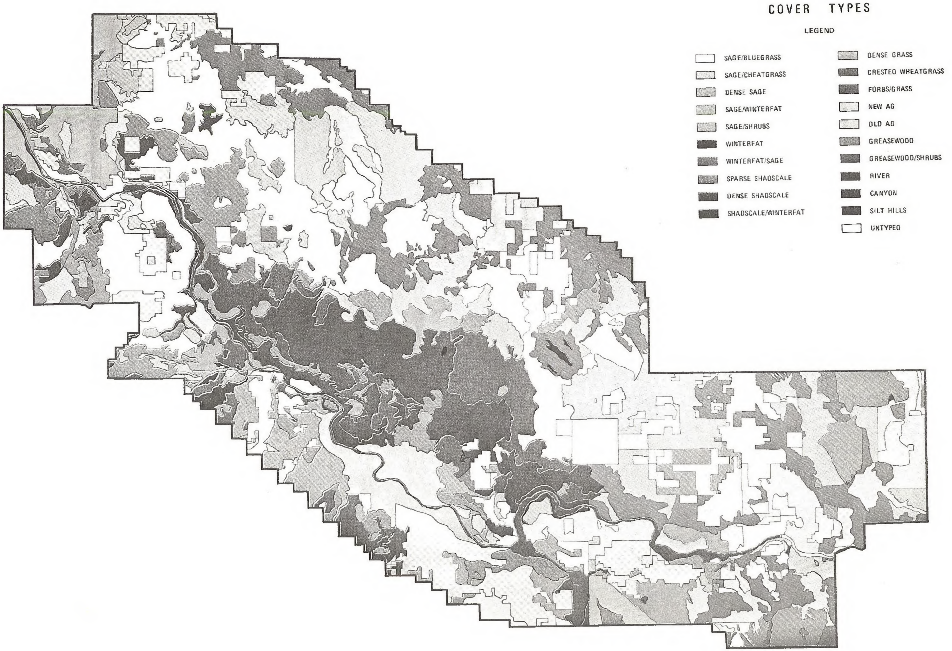
Type Name	Description
Sage/bluegrass	1-20% big sagebrush (*Artemisia tridentata*) 1-20% perennial grasses (esp. *Poa sandbergii*)
Sage/cheatgrass	1-20% big sagebrush; annual grasses only (1-78%) (esp. cheatgrass, *Bromus tectorum*)
Dense sage	> 20% big sagebrush
Sage/shrubs	1-20% sagebrush; miscellaneous shrubs
Sage/winterfat	2-16% winterfat; > 20% big sagebrush
Winterfat/sage	2-20% winterfat; 1-20% sagebrush
Winterfat	5-20% winterfat (*Cerratoides lanata*); no big sagebrush
Shadscale/winterfat	Both shadscale and winterfat present
Sparse shadscale	1-9% shadscale (*Atriplex confertifolia*); no big sagebrush or winterfat
Dense shadscale	≥ 10% shadscale, no sage or winterfat
Greasewood	1-60% greasewood (*Sarcobatus vermiculatus*) - pure stands
Greasewood/shrubs	Greasewood; miscellaneous shrubs
Crested wheatgrass	*Agropyron desertorum* seedings
Forbs/grass	Pure forbs or 1-20% bluegrass or cheatgrass
Dense grass	> 20% cheatgrass or bluegrass
New agriculture	Farmed areas; sprinkler irrigation; large fields; no fence rows
Old agriculture	Farmed areas; gravity irrigation; small fields; fence rows
Canyon	Canyon rim, talus, riparian and rocky areas
Silt hills	Silt hills and sand

Table 5. Areas and relative proportions of cover types in the BPSA.

Cover Type	Hectares	% of Area
Sage/bluegrass	39,280	11.6
Sage/cheatgrass	37,424	11.1
Dense sage	35,729	10.5
Sage/shrubs	9,849	2.9
Sage/winterfat	4,668	1.4
Winterfat/sage	7,550	2.2
Winterfat	5,728	1.7
Shadscale/winterfat	21,516	6.3
Sparse shadscale	11,905	3.5
Dense shadscale	17,810	5.3
Greasewood	11,647	3.4
Greasewood/shrubs	282	0.1
Crested wheatgrass	10,349	3.1
Forbs/grass	40,608	12.0
Dense grass	3,309	1.0
New agriculture	42,255	12.5
Old agriculture	22,293	6.6
Canyon	6,676	2.0
Silt hills	1,274	0.4
River	4,564	1.3
Untyped	4,062	1.2
TOTAL	338,778	100.1

Fig. 8. Distribution of cover types in the BPSA.

The map of cover types reflects the distribution of soils in the BPSA, with the deep loess soils on the north supporting stands of sagebrush and winterfat, and the shallow alluvial soils on the south supporting greasewood and shadscale. In the north central portion of the BPSA, where shadscale predominates, a thin layer of loess soil covers massive basalt flows. The distribution of cover types forms the basis for the distribution of prey in the BPSA.



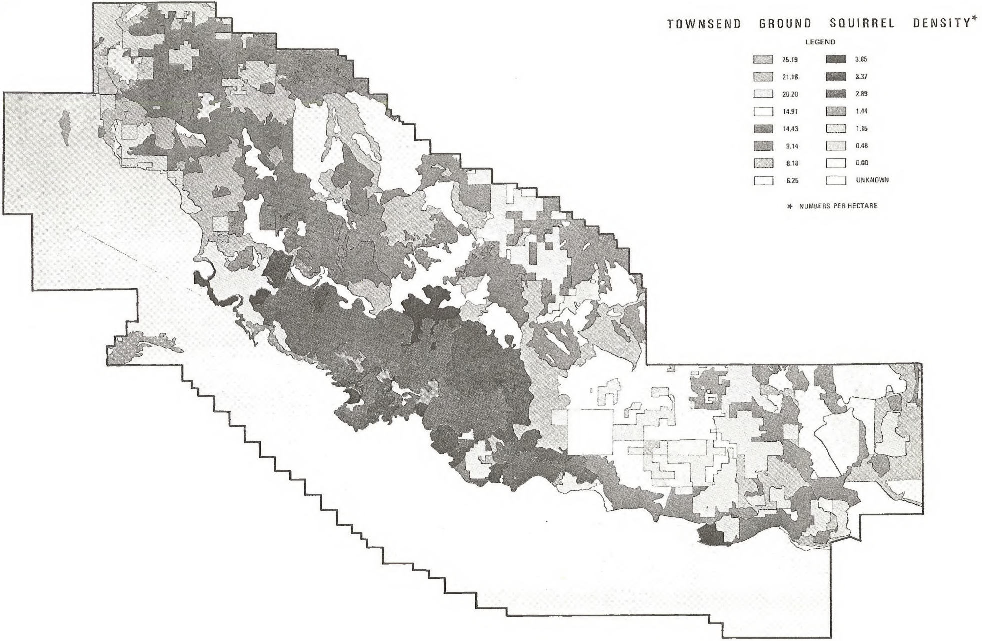
DISTRIBUTION OF COVER TYPES IN THE BPSA

various recreation opportunities that include sightseeing, camping, picnicking, boating, off-road vehicle use, fishing, and hunting.

The Idaho National Guard conducts military maneuvers on 49,653 ha of public land within the BPSA under a permit from the BLM. The present activities, concentrated in June, July, and August, involve firing of tank cannons, mortars, and other field artillery. There are extensive tank maneuvers, personnel movements, and bivouacing. Much of the activity is weekend reserve training with numerous two-week summer camps.

Development of locatable minerals in the BPSA is limited to clay and placer gold. Although some oil and gas rights have been leased, there is currently no oil or gas development or production in the BPSA.

THE PREY



DISTRIBUTION OF TOWNSEND GROUND SQUIRRELS IN THE BPSA, APRIL 1976

Based on the relative amount of each cover type, average April ground squirrel density throughout the BPSA from 1975-78 was 2.32/ha. Most squirrels were found at the northwest corner of the BPSA because of the presence of preferred cover types in that area (Fig. 9). No ground squirrels were found in the Comparison Area between Hammett and Bliss.

Squirrel densities were highest in 1975 and 1976. A drought in winter 1976 and spring 1977 reduced March squirrel densities slightly and April densities substantially (Tables 6 and 7). Squirrels did not reproduce in 1977 on sites supporting natural vegetation north of the river. None of the 36 females collected and examined north of the river in 1977 was pregnant. Females apparently did not come into breeding condition, and no copulation or ovulation occurred. This response was presumably due to the absence of green forage. March squirrel densities in 1978 were 50% lower than 1975-76 densities, reflecting the absence of yearlings in the population. April 1978 densities were 25% of those observed in 1975-76. The population of *S. t. mollis* south of the Snake River bred in 1977, but few young survived. In 1977, 18 of 31 *S. t. mollis* females collected had embryos or placental scars. In contrast, all 17 *S. t. mollis* females examined in 1976 were pregnant.

Of 484 adult and yearling ground squirrels trapped in all years, 43% were males and 57% were females. Weights of adults and yearlings averaged 166.2 g in March of 1977 and 158.3 g in March of the three non-drought years. Squirrels weighed more in the 1977 drought year because energy that would have been invested in reproduction was instead diverted to individual weight gain for earlier estivation. April adult and yearling weights averaged 221.6 g in 1977 and 173.2 g in all other years. Average juvenile weights were 78.7 g. Based on these values, estimates of squirrel biomass per hectare according to cover type for 1975-78 ranged from 0 to 839 g in March (Table 6), and 0 to 2,509 g in April (Table 7).

Small Rodents

Deer mice, Great Basin pocket mice (*Perognathus parvus*), Ord's kangaroo rats (*Dipodomys ordii*), grasshopper mice (*Onychomys leucogaster*), canyon mice (*Peromyscus crinitus*), and least chipmunks (*Eutamias minimus*) were captured in snap traps in the BPSA during July 1975-78 (Appendix A). Great Basin kangaroo rats (*Dipodomys microps*) and western harvest mice (*Reithrodontomys megalotis*) were captured during other times of the year.

Overall, deer mice were significantly more abundant than the other small rodents during every year ($P < 0.001$ in each year). The only other rodent found in relatively high densities was the kangaroo rat (Appendix A).

Deer mice had significantly higher indexes of abundance in canyon talus and canyon riparian areas ($F = 2.98$; df = 13,44; $P < 0.005$) than in other cover types. Kangaroo rats were more numerous near farms or road edges, and Great Basin pocket mice were more abundant in the canyon talus. All other rodents had very low indexes of abundance in all cover types. Least chipmunks were trapped only in sagebrush areas, and canyon mice were restricted to the canyon.

METHODS OF STUDY: PREY

Ground Squirrels

Townsend ground squirrels were live-trapped twice weekly from early February through mid-June 1975-78 at six sites in different cover types in the BPSA. Twenty Sherman traps baited with apple were set at each of the six 1-ha trapping grids and were checked at least four times daily. Trapped squirrels were anesthetized with di-ethyl ether, weighed, and permanently marked by toe-clipping. Density estimates at each site were calculated from recapture frequencies using the maximum likelihood estimator (Eberhardt 1969, Overton 1971).

In 1977 and 1978 ground squirrel burrows were counted along 373 systematically selected transects covering the entire BPSA. Each transect was 200 m x 10 m (0.2 ha), and transects were spaced 3.2 km apart. One transect ran through each of the six intensively trapped sites. A relationship between estimated squirrel densities and number of burrow holes was established for each of the six trapped sites. Squirrel densities in cover types in which trapping was conducted were estimated by comparing the average number of burrow holes for all transects within a cover type with the number of burrow holes on the trapping grid in that cover type. Squirrel densities in cover types that were not trapped were estimated by linear interpolation assuming that the relationship between density and burrow hole counts holds across all cover types. In spring 1979 the Comparison Area from Hammett to Bliss was surveyed on foot and from vehicles for ground squirrel presence.

Small Rodents

Small rodents were live-trapped at one grid in each of eight different cover types in 1975. Live-trap grids consisted of a 10 x 10 arrangement of Sherman traps spaced at 15 m intervals. Traps baited with a mixture of peanut butter and rolled oats were operated for 5-night periods in spring, summer and fall. Animals were marked by toe-clipping.

Live-trapping data were analyzed with the aid of a computer program that calculated the number of animals per unit area by the methods of Schumacher and Eschmeyer (1943), Jolly (1963, 1965) and Overton (1965).

Concurrent with live-trapping in 1975, lines of 50 snap-traps spaced at 15 m intervals and baited with peanut butter and rolled oats were set 500 m from the live-trap grids. A relative index of abundance was calculated from the snap trapping according to the formula:

$$\text{Number of Captures Per Hundred Trap Nights} = \frac{(\text{Captures})\ (100)}{(\text{Trap Nights}) - (\text{Sprung \& Missing Traps})}$$

A relationship between 1975 snap-trap indexes and 1975 live-trapping density estimates for deer mice (*Peromyscus maniculatus*) was determined through regression analysis. Snap-trapping continued at 34 sites in 1976 and 14 sites in 1977-78. Density estimates for each year and each cover type were obtained by applying the regression formula obtained in 1975.

Woodrats (*Neotoma* spp.) were captured in cottontail traps (see section on cottontails), and densities were estimated by a modified removal method (Otis et al. 1978).

Jackrabbits

Yearly jackrabbit trends were assessed by flushing transects and counts of jackrabbits seen during regular activities of the raptor survey crew. Spotlight transects were used to estimate densities and to assess relative jackrabbit abundance by cover type.

From 1972 through 1978, 26 to 60 flushing transects (Gross et al. 1974) were walked in October. Transects were 1.6 km in length and were evenly distributed throughout the BPSA. To supplement the BPSA walking transect data on yearly trends, 1970 and 1971 data from northern Utah (Stoddart, unpublished data) were incorporated in the analysis. This incorporation is appropriate because both the BPSA and northern Utah have similar cover types, and jackrabbit index values for the two areas were nearly the same from 1972 through 1977 (Stoddart, unpublished data). Both Gates density indexes (Gross et al. 1974) and the average number of rabbits seen per transect were tabulated from the walking transect data.

To supplement the data on yearly trends for 1971, 1973, and 1975-78, the average number of jackrabbits seen each day by a 2-person raptor survey crew was tabulated from field notes. These data were summarized for the period from late March through July.

During 1977 and 1978, jackrabbits were censused using a "modified area-estimate method" (Flinders and Hansen 1973) to assess absolute densities and relative jackrabbit abundance by cover type. Four transect routes averaging 22 km in length were established in the BPSA. Each transect was censused with a handheld spotlight (100 watt, 12 volt, 200,000 candlepower) on 3 nights from mid-May through mid-June in a randomized block sampling design. The census vehicle was driven 10 to 16 km/h and both sides of the transect line were observed. Effective sighting distance was established at 50 m on a side, creating a 100 m wide transect. In each cover type sampled, a density correction factor accounted for sighting variability due to compositional and structural differences among cover types (Flinders and Hansen 1973). If there was no modified area estimate for a particular cover type, a density was estimated by averaging the densities in similar cover types. Because the greasewood cover type was not adequately sampled by the spotlight transects, densities in greasewood were estimated using the Gates Index Value.

To extrapolate densities for other years, 1977-78 densities were multiplied by two separate conversion factors, one each for good and poor year types. For good year types, the multiplier was calculated as follows:

$$\frac{\dfrac{(\bar{x}\text{ 1970-71 Fall Gates Index})}{(\bar{x}\text{ 1973-75 Fall Gates Index})} + \dfrac{(\bar{x}\text{ 1971 Rabbits/Crew Day})}{(\bar{x}\text{ 1973-75 Rabbits/Crew Day})}}{2}$$

Since there were no Gates indexes for the BPSA in 1970 and 1971, indexes from northern Utah (Stoddart pers. comm.) were used.

For poor year types, the multiplier was calculated as follows:

$$\frac{\dfrac{(\bar{x}\ 1973\text{-}75\ \text{Gates Index})}{(\bar{x}\ 1976\text{-}77\ \text{Gates Index})} + \dfrac{(\bar{x}\ \text{rabbits/transect}\ 1973\text{-}75)}{(\bar{x}\ \text{rabbits/transect}\ 1976\text{-}78)} + \dfrac{(\bar{x}\ \text{rabbits/crew day}\ 1973\text{-}75)}{(\bar{x}\ \text{rabbits/crew day}\ 1976\text{-}78)}}{3}$$

Biomass of jackrabbits in May was calculated by using an average weight of 1,033.2 g per rabbit based on the May age and sex composition of the jackrabbit population in northern Utah (Hoffman, unpublished data). It is assumed that sex and age ratios in the BPSA are similar to those in northern Utah, and that they do not change from one year to another.

Cottontails

Mountain cottontails (*Sylvilagus nuttalii)* were censused using capture-recapture trap lines in 1975-78. Trap lines consisting of 8 to 12 live-traps were placed 30 m apart in selected cover types throughout the study area for a period of 10-12 days. In 1975, 1976, 1977, and 1978, 8, 8, 36, and 33 sites were trapped, respectively. Three of these sites (canyon riparian, canyon talus, and canyon rim) were trapped each season of each year. Densities were estimated from live-trapping data by the frequency of capture method (Edwards and Eberhardt 1967).

Because cottontails in the BPSA are mostly restricted to rocky areas, cottontail densities on the desert plateau surrounding the canyon were assessed by estimating the amount of suitable rocky habitat from aerial photos. The percent of rocky habitat in each of 80 randomly selected 2.5 km^2 blocks was estimated using a stereoscope. Twenty-six blocks were surveyed from a helicopter to validate the amount of rocky area estimated in the lab. Estimates of cottontail densities in rocky areas were derived from trapping studies and were multiplied by the average proportion of rocky area in the 80 blocks to yield a density estimate for the entire desert plateau. To supplement this information on distribution and habitat preference, a 375-km^2 area characterized by agricultural development was surveyed for indications of cottontail presence. In 1978, 255 transect lines were walked within the area, and local residents were interviewed to assist in locating cottontail populations.

Yellow-bellied Marmots

Marmot (*Marmota flaviventris*) colony distribution was surveyed by walking along the base of the Snake River canyon in 1975. During 1978, an intensive effort was made to qualitatively determine the cover types used by marmots and to describe marmot distribution in areas of both agriculture and native vegetation. Approximately 1,300 km^2 within the BPSA were surveyed both visually and by interviewing local residents. Additional information on marmot distribution was gathered from incidental captures during cottontail trapping. Marmot colony locations were plotted on USGS 1:24,000 scale maps. Probable colony size, land use, and any geographic features that might influence marmot distribution were recorded.

Marmots were live-trapped at a 2.5 ha rocky outcrop near the Snake River south of Melba, Idaho from February through March, 1976, 1977, and 1978. In 1978, four additional areas in and near the BPNA were trapped for marmots. Densities were estimated by both the frequency of capture method (Edwards and Eberhardt 1967) and the Schnabel index (Giles 1971).

Pheasants

Estimates of ring-necked pheasant (*Phasianus colchicus*) densities were obtained by the crow-count method (Kimball 1949) during the last half of April and the first part of May 1976-78. Routes were selected in an attempt to determine possible differences in pheasant abundance between areas of old and new agricultural practices. Four routes were located in old agricultural habitat types and four were in new agriculture. Numbers of calls per station were converted to densities according to Kimball's (1949) formula. Idaho Fish and Game Department data on brood size, sex ratios, and hearing distances for the area and for each particular year were used to complete the calculations.

Passerines and Other Birds

Passerines were censused by walking transects (Emlen 1971) in spring and summer 1978. Eight square transects (0.5 km on each side) were set up in each of 10 cover types throughout the BPSA. Transects were walked in early morning, once in April-May and once again in June-July. Bird densities in each vegetation type were then calculated for each 2-month sample period after Emlen (1971).

Reptiles

Lizards were censused by an observational strip census technique (Degenhardt 1966) from 1975-78. Eighteen transects were established in different cover types in the BPSA. Each transect was walked during the seasonal and daily peak of lizard activity. The area censused was computed by multiplying transect length by twice the average maximum distance of detection for each lizard species. The density index for each species was calculated as the maximum number of individuals encountered during any one census divided by the area censused.

Snake densities were estimated from the number of snakes captured in drift fences. Four drift fences in 1977 and 12 in 1978 were placed in different representative cover types during the snakes' seasonal activity periods. Each fence consisted of 30 m sections of galvanized tin 51 cm high with two "snake traps" located 7.6 m from each end. The snake traps were 1.2 x 0.6 x 0.3 m boxes constructed from 3.2 mm (1/8 inch) hardware cloth. Funnels led into the trap from both ends.

Drift fence captures were converted to density estimates by assuming that all snakes within one average home range radius of the drift fence were trapped. Snake home ranges were assumed to be circular, and their sizes were estimated from the literature (Fitch 1948, Fitch 1958, McNab 1963, Barbour et al. 1969, Hirth et al. 1969, Parker 1974). Western rattlesnake (*Crotalus viridis*) home ranges were estimated by the convex polygon method (Jennrich and Turner 1969).

Both a removal census and a mark-recapture study supplemented drift fence estimates of rattlesnake density. At one site all rattlesnakes encountered were collected, and the area was searched intensively for 5 days until no more rattlesnakes could be found. The total number removed was assumed to be the total population. At other sites where high densities were suspected, snakes were captured, marked with a heat brand, and released. When no unmarked snakes were captured after repeated efforts, the total number marked was assumed to be the total population.

RESULTS: PREY

Townsend Ground Squirrels

Because of the abundant cheatgrass and soil textures suitable for burrowing, the BPSA supports high Townsend ground squirrel populations. Ground squirrel densities at the six intensively trapped sites ranged from 0.7/ha to 20.2/ha.

Adult male ground squirrels emerged from torpor in late January. Adult females and yearlings emerged 1-2 weeks later, and females were bred soon after emergence. Litters were first seen above ground from late March to early April. Normally the number of active squirrels decreased in mid-May, when adult males entered torpor. Adult and yearling females entered torpor in early June in normal years. Juveniles usually began dormancy from mid-June to mid-July. In a typical year, all age and sex classes were simultaneously active above ground for only 4 weeks, with 100% of the population above ground from mid-April to mid-May, 77% in late May, and 46% in early June. By mid-July of most years, virtually all squirrels had entered torpor. During 1977, however, estivation in native range was almost two months earlier, and all squirrels were underground by mid-May.

Ground squirrel densities in the major cover types during early March of 1975-78 ranged from 0 to 5.3/ha (Table 6). April densities ranged from 0 to 25.5/ha (Table 7). The higher April densities reflect the emergence of juveniles and the annual peak of squirrel numbers.

Winterfat, dense grass, and winterfat/sage associations had more squirrels than any other cover types, with 20.2, 21.2 and 25.5/ha respectively in April 1976 (Table 7). Greasewood, canyon, and silt hills habitats did not support Townsend ground squirrels. Ground squirrels did not occur within crop land except in some alfalfa fields. Farmers regularly poison squirrels in alfalfa fields, however, and overall squirrel density in farmland is low.

Except at one isolated area, Townsend ground squirrels did not occur south of the Snake River (Fig. 9). The isolated population south of the river is a separate subspecies, *Spermophilus townsendi mollis*, that is distinct from the subspecies *S. t. idahoensis* found north of the river. Studies have documented biochemical differences between the two populations (Nadler 1966).

Table 6. Estimated March 1 Townsend ground squirrel densities (individuals/ha) and biomass (g/ha, in parentheses) in BPSA cover types north of the river, 1975-78.

Cover Type	1975	1976	1977	1978
Sage/ bluegrass	3.0 (480)	3.0 (475)	2.4 (399)	1.5 (238)
Sage/ cheatgrass	1.7 (269)	1.7 (269)	1.4 (226)	0.9 (135)
Dense sage	1.3 (206)	1.3 (206)	1.0 (273)	0.7 (103)
Sage/ shrubs	0.8 (13)	0.8 (13)	0.6 (100)	0.4 (63)
Sage/ winterfat	3.1 (491)	3.1 (491)	2.5 (412)	1.6 (245)
Winterfat/ sage	5.3 (839)	5.3 (839)	4.2 (705)	2.7 (420)
Winterfat	4.2 (665)	4.2 (665)	3.4 (558)	2.1 (332)
Shadscale/ winterfat	0.6 (95)	0.6 (95)	0.5 (80)	0.3 (48)
Sparse shadscale	0.3 (48)	0.3 (48)	0.2 (40)	0.2 (24)
Dense shadscale	0.7 (111)	0.7 (111)	0.6 (93)	0.4 (55)
Greasewood	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Greasewood/ shrubs	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Crested wheatgrass	0.1 (16)	0.1 (16)	0.1 (13)	0.1 (8)
Forbs/ grass	1.9 (301)	1.9 (301)	1.5 (253)	1.0 (150)
Dense grass	4.4 (697)	4.4 (697)	3.5 (585)	2.2 (348)
New agriculture	0.2 (38)	0.2 (38)	0.2 (32)	0.1 (19)
Old agriculture	0.2 (38)	0.2 (38)	0.2 (32)	0.1 (19)
Canyon	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Silt hills	0.0 ---	0.0 ---	0.0 ---	0.0 ---

Table 7. Estimated April 10 Townsend ground squirrel densities (individuals/ha) and biomass (g/ha, in parentheses) in BPSA cover types north of the river, 1975-78.

Cover Type	1975	1976	1977	1978
Sage/ bluegrass	7.7 (886)	14.4 (1420)	2.4 (532)	2.8 (358)
Sage/ cheatgrass	4.3 (503)	8.2 (805)	1.4 (301)	1.6 (203)
Dense sage	3.3 (384)	6.3 (615)	1.0 (231)	1.2 (155)
Sage/ shrubs	2.0 (236)	3.9 (379)	0.6 (142)	0.7 (95)
Sage/ winterfat	7.9 (916)	14.9 (1468)	2.5 (550)	2.0 (370)
Winterfat/ sage	13.5 (1566)	25.5 (2509)	4.2 (940)	4.9 (632)
Winterfat	10.7 (1240)	20.2 (1988)	3.4 (745)	3.8 (501)
Shadscale/ winterfat	1.5 (177)	2.9 (284)	0.5 (106)	0.6 (72)
Sparse shadscale	0.8 (89)	1.4 (142)	0.2 (53)	0.3 (35)
Dense shadscale	1.8 (207)	3.4 (332)	0.6 (124)	0.6 (84)
Greasewood	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Greasewood/ shrubs	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Crested wheatgrass	0.3 (30)	0.5 (47)	0.1 (18)	0.1 (12)
Forbs/ grass	4.9 (562)	9.1 (900)	1.5 (337)	1.7 (267)
Dense grass	11.2 (1300)	21.2 (2083)	3.5 (780)	4.0 (525)
New agriculture	0.6 (71)	1.2 (113)	0.2 (44)	0.2 (29)
Old agriculture	0.6 (71)	1.2 (113)	0.2 (44)	0.2 (29)
Canyon	0.0 ---	0.0 ---	0.0 ---	0.0 ---
Silt hills	0.0 ---	0.0 ---	0.0 ---	0.0 ---

Fig. 9. Distribution of Townsend ground squirrels in the BPSA, April 1976.

The highest ground squirrel densities are found in the northwest corner of the BPSA because of the preferred soils and cover types in that area. Ground squirrels do not occur south of the Snake River except at one isolated tract, where a population representing a separate subspecies (S. t. mollis) exists.

Kill trap indexes and live trapping density estimates for deer mice in 1975 were highly correlated (r = 0.992 for sagebrush types; r = 0.997 for other cover types). The least squares regression equation for sagebrush had a significantly different slope from the equation for non-sagebrush cover types (F = 101.1; df = 1,7; P < 0.01). The relationship

$$y = 1.971 + 0.828x,$$

where y = rodent number per ha and x = number of captures per 100 trap nights, was used to obtain densities of both deer mice and other species in sagebrush habitats (Table 8). The equation

$$y = 1.985 + 3.568x$$

was applied to the values for non-sagebrush habitats.

Deer mouse densities ranged from 0/ha in some cover types to 136.2/ha in forb/grass associations in 1975 (Table 8). No single cover type had the highest densities in all years, but canyon densities were high in all 3 years. Estimates of biomass, using weights from Appendix B, ranged as high as 2,588g/ha (Table 8).

Woodrats were the other common small rodent species in the BPSA. Neither the bushy-tailed woodrat (*Neotoma cinerea*) nor the desert woodrat (*Neotoma lepida*) was susceptible to snap-trapping, but both species were captured in cottontail traps. There was no statistically significant difference in the number of bushy-tailed woodrats captured per 100 trap nights among years (F = 0.54; df = 12,20; P > 0.25) or among trap sites within the canyon (F = 0.46; df = 10,20; P > 0.25). Desert woodrats were captured at the canyon rim and were observed in riparian cover. Estimated woodrat density in the canyon averaged 1.6/ha for all years. Both species exhibited a habitat preference for rocky outcrops and talus slopes, and were not found in the desert unless suitable rocky cover was located nearby.

The entire study area was estimated to contain an average of 52.9 individual rodents per hectare excluding ground squirrels. Rodent populations other than ground squirrels were concentrated in the canyon (Fig. 10).

Jackrabbits

Gates transect indexes, the average number of jackrabbits seen per transect, and the number of jackrabbits seen per research crew day all showed the same general trend from 1970 to 1978 (Fig. 11). Jackrabbit numbers were assumed to be at a peak in 1970 or early 1971, based on the observed population changes in nearby Curlew Valley, Utah, approximately 250 km from the BPSA (Stoddart, pers. comm.). Populations declined in 1972 and reached a low in 1973, 1974, and 1975. In 1976-78 numbers increased, but in 1978, indexes of abundance were still well below the 1971 level.

Table 8. Estimated rodent densities (individuals/ha) and biomass (g/ha, in parentheses) in relation to cover types in the BPSA, based on July snap-trapping.

	Peromyscus maniculatus				Other*		
Cover Type	1975	1976	1977	1978***	1975	1976	1977
Sage/bluegrass Sage/cheatgrass Dense sage	9.1 (173)	16.5 (314)	12.6 (239)	9.2 (174)	2.9 (87)	6.7 (201)	12.8 (384)
Sage/shrubs	25.4 (482)	50.9 (966)	21.6 (409)	13.1 (249)	12.5 (373)	3.4 (101)	6.4 (192)
Sage/winterfat Winterfat/sage	** **	106.6 (2025)	103.0 (1947)	18.8 (356)	** **	30.0 (900)	17.7 (531)
Winterfat	19.8 (377)	70.5 (1340)	17.0 (322)	0 ---	11.1 (333)	25.0 (750)	24.5 (735)
Shadscale/winterfat	** **	45.5 (865)	37.0 (702)	** **	** **	9.1 (273)	38.6 (1158)
Sparse shadscale Dense shadscale	41.6 (791)	85.2 (1618)	30.5 (580)	17.0 (322)	22.0 (660)	0 ---	0 ---
Greasewood	** **	** **	113.7 (2161)	38.8 (736)	** **	** **	17.0 (510)
Greasewood/shrubs	9.1 (173)	16.5 (314)	63.2 (1200)	24.0 (456)	2.9 (87)	6.7 (201)	14.9 (477)
Crested wheatgrass	** **	31.8 (604)	** **	** **	** **	0 ---	** **
Forbs/grass	136.2 (2588)	60.2 (1143)	26.3 (499)	** **	6.6 (198)	71.1 (2133)	50.5 (1515)
Dense grass	17.7 (336)	54.1 (1028)	17.0 (322)	21.4 (407)	0 ---	10.6 (318)	0 ---
New agriculture	** **	38.7 (735)	** **	** **	** **	0 ---	** **
Old agriculture	** **	53.9 (1024)	** **	** **	** **	11.7 (351)	** **
Canyon	105.3 (2001)	121.6 (2310)	89.3 (1697)	130.9 (2486)	23.4 (702)	44.1 (1323)	9.1 (273)
Silt hills	** **	0 ---	** **	** **	** **	23.0 (690)	** **

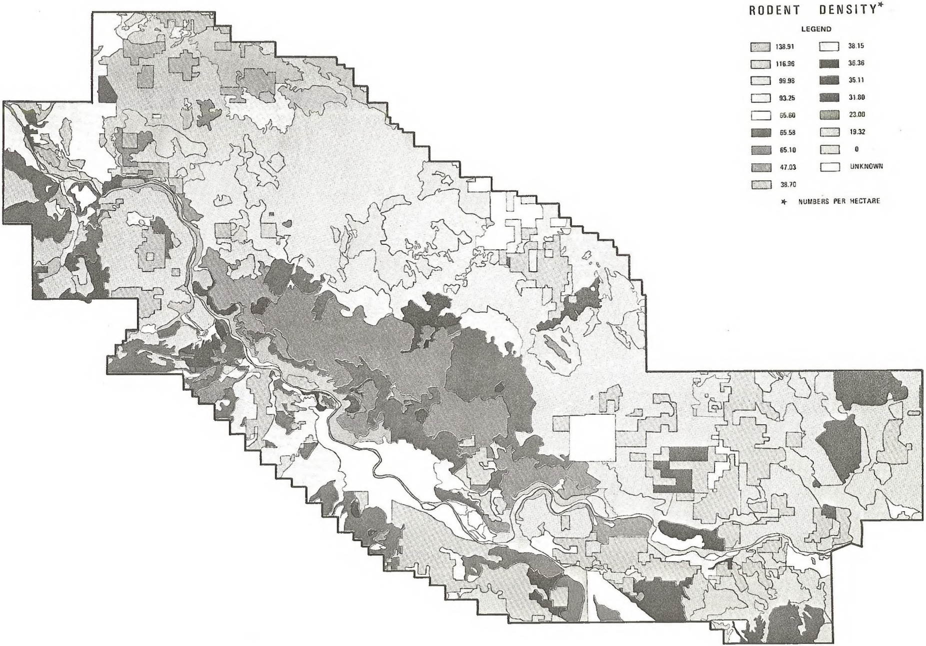
* Includes Great Basin pocket mouse (Perognathus parvus), kangaroo rat (Dipodomys sp.), grasshopper mouse (Onychomys leucogaster), canyon mouse (Peromyscus crinitus), and least chipmunk (Eutamias minimus).

** Not Sampled.

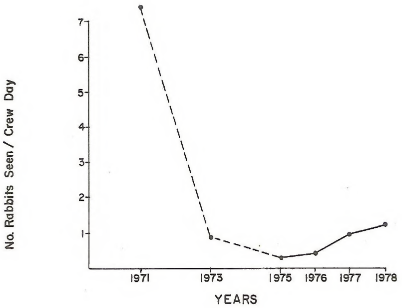
*** Trapping results could not yield density estimates for other species in 1978.

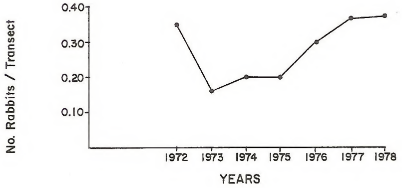
Fig. 10. Distribution of rodents other than Townsend ground squirrels in the BPSA.

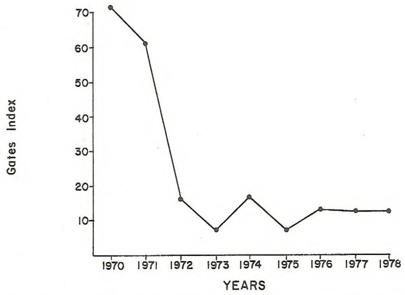
Small rodent populations in the BPSA are higher along the canyon than in the desert plateau. Canyon talus, canyon rim, and riparian situations support more woodrats, deer mice, and other small rodent species than the other desert cover types.



DISTRIBUTION OF RODENTS OTHER THAN TOWNSEND GROUND SQUIRRELS IN THE BPSA







BLACK–TAILED JACKRABBIT POPULATION TRENDS INDICATED BY THREE METHODS

Estimates of jackrabbit densities by cover type and year type are shown in Table 9. Jackrabbits were most abundant in sagebrush cover, and greasewood and shadscale were the next most important cover types. Winterfat/sage associations supported moderate densities, but few jackrabbits were found in pure winterfat stands or grass areas. Agricultural areas did not support jackrabbit populations (Fig. 12).

Mountain Cottontails

Canyon areas within the BPSA supported higher cottontail densities than areas in the desert plateau. Canyon talus and riparian sites supported more cottontails than areas along the canyon rim. Estimated density in the canyon (talus, riparian, and canyon rim), based on frequency of capture methods and pooled for 1975-78, was 3.7 rabbits per ha. No significant differences were observed among yearly densities ($F = 1.98$, $df = 30$, $P > .15$). Over the four years the canyon averaged 5.19 cottontails captured per 100 trap nights; rocky outcrops in the desert plateau averaged 2.59 captures per 100 trap nights. Density indexes among desert cover types did not differ as long as rocks were present. Few cottontails inhabited native desert vegetation unless there was a rocky outcrop or similar cover present. Sites with native vegetation containing no rocky areas averaged only 0.37 cottontails caught per 100 trap nights. Captures at farm ecotones were lower than at rocky outcrops, averaging 1.86 per 100 trap nights.

Both trapping results and intensive surveys of agricultural lands suggested that farming does not increase rabbit abundance at its edge except near permanent cover (old buildings, rock piles, and abandoned farm machinery). Three of four farm ecotones trapped in 1977 showed no increase in cottontails when compared with the surrounding native vegetation. Habitat for cottontails is eliminated within cultivated fields. Modern farms support fewer cottontails at their edges than older farms because of the larger fields, reduced cover, and absence of fence rows.

Analysis of aerial photos indicated that approximately 4% of the native desert area in the BPSA contained rocky outcrops. Cottontail densities in these rocky outcrops were 50% of that in the canyon, or approximately 1.85 rabbits per hectare. Therefore, in May-June 1975-78 the 323,476 ha of desert cover in the BPSA supported an estimated 24,000 cottontails, while the 6,676 ha of canyon contained an estimated 25,000 rabbits.

Yellow-bellied Marmots

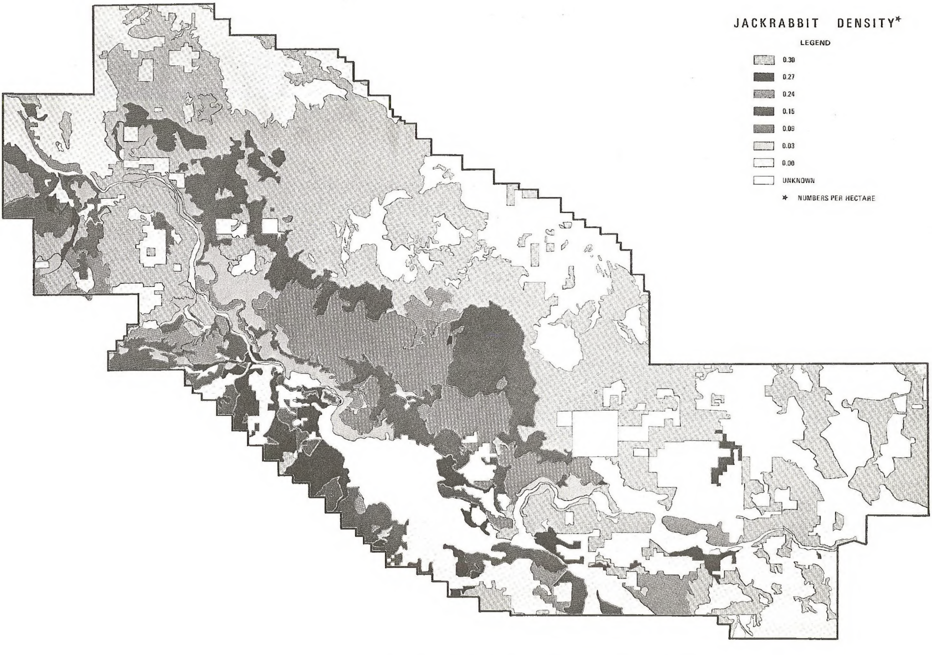
Marmots were found in the BPSA only where there was sufficient topographic diversity for burrow sites and adequate succulent vegetation. No marmots were seen in native desert cover types, presumably due to lack of succulent vegetation. Farming allowed colonization by marmots only if the farm edge was located near good burrow sites and rich vegetation. The canyon cover type, with an open water source and rich riparian vegetation, supported virtually all of the marmot colonies in the BPSA. Burrow sites were located mainly on talus slopes. Surveys indicated that approximately 10% of the canyon habitat was inhabited by marmots.

Table 9. May jackrabbit densities (individuals/ha) and biomass (g/ha in parentheses) by cover type and year type in the BPSA.

	Densities by year type		
Cover Type	Good 1971	Average 1977-78	Poor 1973-75
Sage/bluegrass Sage/cheatgrass Dense sage	1.77 (1829)	0.30 (310)	0.20 (207)
Sage/shrubs	1.42 (1467)	0.24 (248)	0.16 (165)
Sage/winterfat Winterfat/sage	0.89 (920)	0.15 (155)	0.10 (103)
Winterfat	0.18 (186)	0.03 (31)	0.02 (21)
Shadscale/winterfat	0.53 (548)	0.09 (93)	0.06 (62)
Sparse shadscale Dense shadscale	0.88 (909)	0.15 (155)	0.10 (103)
Greasewood	1.59 (1643)	0.27 (279)	0.18 (186)
Greasewood/shrubs	1.59 (1643)	0.27 (279)	0.18 (186)
Crested wheatgrass Forbs/grass Dense grass	0.0 ---	0.0 ---	0.0 ---
New agriculture	0.0 ---	0.0 ---	0.0 ---
Old agriculture	0.0 ---	0.0 ---	0.0 ---
Canyon	0.18 (186)	0.03 (31)	0.02 (21)
Silt hills	0.0 ---	0.0 ---	0.0 ---
River	0.0 ---	0.0 ---	0.0 ---

Fig. 12. Distribution of black-tailed jackrabbits in the BPSA, May 1978.

Sagebrush cover types support the highest concentration of jackrabbits in the BPSA. Much of the best jackrabbit habitat is located more than 3 km from the canyon, and the majority of it is north of the river. Although jackrabbits sometimes feed at the edges of alfalfa fields, agricultural areas as a whole do not support jackrabbit populations. Unlike ground squirrels, jackrabbits show no distinct density changes from east to west.



DISTRIBUTION OF JACKRABBITS IN THE BPSA, MAY 1978

At the intensively trapped marmot colony near Melba, the Schnabel estimate of density was 15.9/ha in 1976 and 13.5/ha in 1977. Two other areas trapped in 1978 yielded Schnabel density estimates of 10.0/ha and 10.5/ha.

Adult marmots emerged in February and estivated in June and July. Juveniles emerged in April and estivated in July. Frequency of capture estimates based on the above data, pooled for all three colonies in all years, were 14.7/ha in April and 10.8/ha in June. The sex ratio of all trapped marmots was 1.25 males:1.0 females (n = 44). Weights varied from 900 to 2,500 g for adult females ($\overline{x}$ = 2,020, n = 17) and 1,100 to 4,150 g for adult males ($\overline{x}$ = 2,525, n = 20). In early spring no young-of-the-year were captured, but in late May and early June six immature marmots weighed 700 to 1,600 g ($\overline{x}$ = 920). Five of the six immature marmots captured were females.

Using these ratios and average weights for each size category, estimates of marmot biomass at the three colonies were 30 kg/ha in April and 27 kg/ha in June. Since marmot colonies occurred in only 10% of the sampled canyon habitat, densities throughout the canyon probably range from 1.1/ha to 1.4/ha (2.7 kg/ha - 3.0 kg/ha). The 6,671 ha of canyon habitat in the BPSA support an estimated total of 7,000 to 10,000 marmots.

Ring-necked Pheasants

Pheasants in the BPSA were usually not found more than 4 km from agriculture. April densities based on crow counts for all years were 0.1/ha in old agriculture and 0.028/ha in new agriculture. Densities in old and new agriculture differed significantly (F = 8.896; df = 16, 2; $P < .012$), but pheasant numbers did not differ significantly among years (F = 0.694; df = 16, 2; $P > 0.52$). Clean farming practices associated with new agricultural methods cause a loss of vegetative cover, especially residual nesting cover and winter cover, necessary for pheasant survival.

Passerines and Other Birds

At least 18 species of passerines and other nonraptorial birds were observed along transect lines in the BPSA. Two of the more common birds were horned larks (*Eremophila alpestris*) and western meadowlarks (*Sturnella neglecta*). Species classed as sparrows that were frequently observed included house sparrows (*Passer domesticus*), house finches (*Carpodacus mexicanus*), song sparrows (*Melospiza melodia*), sage sparrows (*Amphispiza belli*), lark sparrows (*Chondestes grammacus*), and Brewer's sparrows (*Spizella breweri*). "Blackbirds" seen included starlings (*Sturnus vulgaris*), red-winged blackbirds (*Agelaius phoeniceus*), and Brewer's blackbirds (*Euphagus carolinus*). Other birds observed on transects included ravens, mourning doves (*Zenaida macroura*), rock doves (*Columba livia*), swallows, kingbirds (*Tyrannus verticalis* and *Tyrannus tyrannus*), California quail (*Lophortyx californicus*), robins (*Turdus migratorius*), gulls, and great blue herons (*Ardea herodias*). Total passerine densities in 1978 were as high as 37.7/ha in late spring (Table 10) and 52.1/ha in summer (Table 11) in certain cover types. Estimates of biomass in relation to cover types, based on weights in Appendix B, ranged from 0 to 1,780 g/ha in spring and 0 to 1,901 g/ha in summer (Tables 10 and 11).

Table 10. Passerine densities (individuals/ha) and biomass (g/ha, in parentheses) for April-May 1978 in the BPSA derived from Emlen transects.

Cover Type	Horned lark	Meadow-lark	"Sparrow"	"Blackbird"	Other*	Total
Sage/bluegrass	0.5	0.6	1.6	0.1	0.4	3.2
Sage/cheatgrass	(13)	(60)	(41)	(9)	(18)	(141)
Dense sage	0.3	0.8	2.1	0.0	0.3	3.4
	(9)	(72)	(54)	---	(13)	(147)
Sage/shrubs	1.2	0.3	1.1	0.0	0.3	2.9
	(31)	(33)	(28)	---	(14)	(105)
Sage/winterfat	2.7	0.2	2.4	0.0	0.5	5.8
Winterfat/sage	(70)	(14)	(63)	---	(25)	(173)
Winterfat	0.9	0.0	0.4	0.0	0.4	1.7
	(23)	(4)	(9)	---	(19)	(55)
Shadscale/winterfat	1.3	0.1	0.5	0.0	0.3	2.1
	(35)	(5)	(12)	---	(14)	(65)
Sparse shadscale	1.8	0.1	0.5	0.0	0.2	2.6
Dense shadscale	(47)	(5)	(14)	---	(9)	(76)
Greasewood	0.1	0.3	1.7	0.0	0.9	3.1
	(4)	(28)	(45)	---	(46)	(122)
Greasewood/shrubs	1.0	0.2	1.1	0.0	0.6	2.8
	(25)	(17)	(29)	---	(27)	(99)
Crested wheatgrass	5.3	0.5	0.3	0.0	0.4	6.5
Forbs/grass	(137)	(44)	(8)	---	(22)	(211)
Dense grass						
New agriculture	1.4	0.3	1.8	0.5	5.5	9.5
	(38)	(28)	(46)	(33)	(275)	(419)
Old agriculture	0.1	0.3	13.6	13.8	9.9	37.7
	(2)	(30)	(353)	(898)	(497)	(1780)
Canyon/riparian	0.0	0.1	3.2	8.7	9.2	21.2
	---	(9)	(83)	(565)	(459)	(1116)
Silt hills	0.0	0.0	0.0	0.0	0.0	0.0
	---	---	---	---	---	---

* includes some non-passerines (e.g. quail, doves)

Table 11. Passerine densities (individuals/ha) and biomass (g/ha, in parentheses) for June-July 1978 in the BPSA derived from Emlen transects.

Cover Type	Horned lark	Meadow-lark	"Sparrow"	"Blackbird"	Other*	Total
Sage/bluegrass	1.2	0.6	8.6	0.0	0.3	10.6
Sage/cheatgrass	(31)	(54)	(223)	---	(16)	(323)
Dense sage	0.4	1.2	5.5	0.0	5.5	12.6
	(11)	(114)	(142)	---	(275)	(542)
Sage/shrubs	2.2	0.3	4.7	0.0	0.2	7.2
	(56)	(28)	(120)	---	(8)	(212)
Sage/winterfat	3.7	0.2	4.0	0.0	0.6	8.5
Winterfat/sage	(96)	(19)	(105)	---	(28)	(248)
Winterfat	3.8	0.0	0.4	0.0	3.0	7.2
	(99)	(2)	(11)	---	(150)	(262)
Shadscale/winterfat	3.5	0.0	0.6	0.0	1.5	5.5
	(90)	(1)	(14)	---	(75)	(181)
Sparse shadscale	3.1	0.0	0.7	0.0	0.0	3.8
Dense shadscale	(81)	(1)	(18)	---	---	(100)
Greasewood	1.0	0.5	1.9	0.0	0.8	4.3
	(27)	(48)	(50)	---	(42)	(167)
Greasewood/shrubs	2.1	0.3	1.3	0.0	0.4	4.1
	(54)	(25)	(34)	---	(21)	(133)
Crested wheatgrass	8.7	0.0	0.1	0.0	0.4	9.2
Forbs grass	(226)	(1)	(2)	---	(19)	(249)
Dense grass						
New agriculture	1.4	0.8	4.4	0.0	1.0	7.4
	(35)	(75)	(113)	---	(48)	(261)
Old agriculture	0.0	0.6	33.7	5.3	12.6	52.1
	---	(54)	(875)	(343)	(628)	(1901)
Canyon riparian	0.0	0.1	0.6	17.2	9.4	27.4
	---	(14)	(17)	(1119)	(472)	(1621)
Silt hills	0.0	0.0	0.0	0.0	0.0	0.0
	---	---	---	---	---	---

* includes some non-passerines (e.g. quail, doves)

The silt hill cover type was the only habitat that did not support passerines. The old agricultural type supported the most passerines in both density and biomass because of the high numbers of sparrows and blackbirds. Sparrows had significantly higher densities in "old" agriculture ($F = 34.5$; $df = 9,75$; $P < 0.001$) than in all other cover types, probably because of high densities of house sparrows. Big sagebrush, riparian, and big sagebrush/winterfat also had high sparrow populations. Blackbirds were most abundant in riparian and agricultural types. Although the number of blackbirds in canyon riparian zones increased from spring to summer, the number in agricultural types did not.

Horned larks were not observed in old agriculture in June and July. Horned larks had significantly higher densities in the grass types than in the other cover types ($F = 19.9$; $df = 9,74$; $P < 0.001$). Sage/winterfat, winterfat, shadscale, and new agriculture cover types also had high horned lark densities, but these were not statistically significant. Meadowlark population densities were highest in sage cover types, but differences among types were not significant.

Based on the abundance of cover types in the BPSA, an estimated 2 million passerines inhabited the BPSA in April 1978. A map of their density distribution is shown in Fig. 13.

Reptiles

Lizards. Lizard densities in the BPSA ranged from 0 to 19.5/ha, depending on cover type (Table 12). No distinct annual differences in lizard densities were apparent, so data were pooled for all years. In general, habitats with high lizard densities had a sparse vegetative cover with many areas of bare ground or rocks.

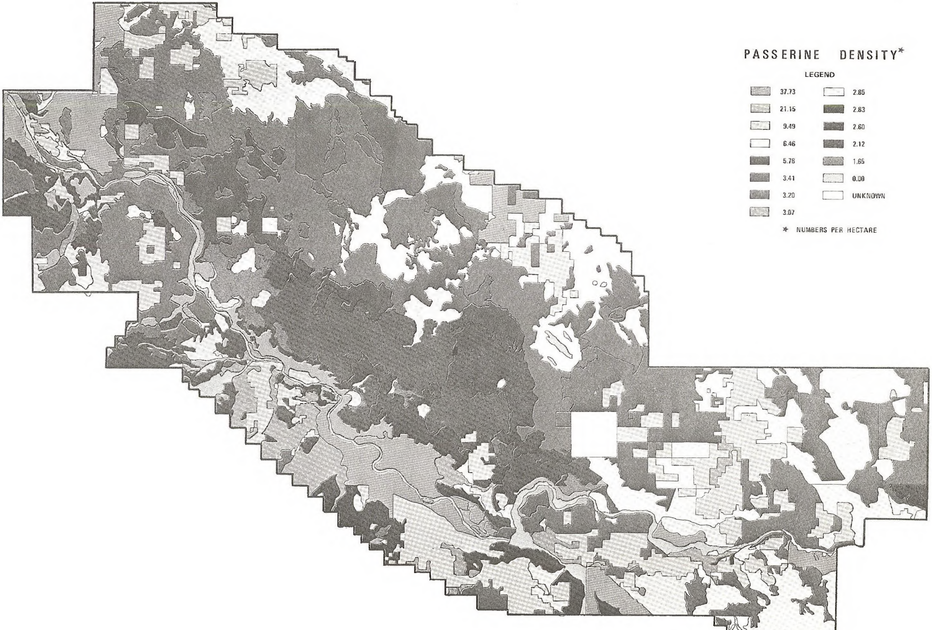
Canyon and shadscale cover types had more species and more individuals per hectare than other habitats (Table 12). Because shadscale habitats in the BPSA comprise three times the area of canyon, shadscale habitats support a greater total number of lizards than the canyon. Most lizards in the canyon zones were found on the talus slopes. Greasewood and riparian habitats hosted moderate lizard populations, while low lizard densities occurred in winterfat, sage, and grass cover types (Table 12). Agricultural areas did not support lizard populations.

Based on the relative abundance of cover types, lizard densities throughout the BPSA averaged 6.56/ha. Side-blotched lizards (*Uta stansburiana*) were the most abundant (Table 12). Western whiptails (*Cnemidophorus tigris*), however, accounted for more lizard biomass than any other species. Western fence lizards (*Sceloporus occidentalis*) had high biomass values per hectare but occurred only in a few restricted habitats. Collared lizards (*Crotaphytus collaris*) and desert horned lizards (*Phrynosoma platyrhinos*) were relatively scarce.

Snakes. In 1978, 151 snakes were captured in drift fences (Table 13). Gopher snakes (*Pituophis melanoleucus*) were captured most frequently, followed by nightsnakes (*Hypsiglena torquata*), western ground snakes (*Sonora semiannulata*), striped whipsnakes (*Masticophis taeniatus*), and western rattlesnakes.

Fig. 13. Distribution of passerines and other birds in the BPSA, April 1978.

An estimated 2 million passerines inhabit the BPSA. Highest densities were in agricultural areas where an abundance of house sparrows, a relatively unimportant raptor prey, inflates the overall totals. Horned larks and meadowlarks, the avian species consumed most often by raptors, are generally restricted to native range cover types.



PASSERINE DISTRIBUTION IN THE BPSA, APRIL 1978

Table 12. Lizard densities (individuals/ha) and biomass (g/ha, in parentheses) in BPSA cover types.

Cover Types	Western Whiptail	Leopard Lizard	Side-blotched Lizard	Desert Horned Lizard	Western Fence Lizard	Collared Lizard	Total
Sage/bluegrass Sage/cheatgrass Dense sage	1.6 (24)	1.8 (42)	2.0 (7)	1.8 (31)	0 ---	0 ---	7.1 (105)
Sage/shrubs 1	2.2 (34)	1.2 (28)	8.4 (31)	1.5 (27)	0 ---	0 ---	13.3 (119)
Sage/winterfat 2 Winterfat/sage 2	1.1 (17)	1.1 (26)	4.7 (17)	1.8 (31)	0 ---	0 ---	8.7 (92)
Winterfat	0.7 (10)	0.5 (10)	7.5 (27)	0 ---	0 ---	0 ---	8.6 (47)
Shadscale/ winterfat	1.0 (15)	0.6 (15)	11.1 (40)	0.6 (10)	0 ---	0 ---	13.3 (80)
Sparse shadscale Dense shadscale	4.1 (62)	1.2 (26)	12.1 (44)	2.2 (39)	0 ---	0 ---	19.5 (171)
Greasewood	4.0 (62)	1.9 (42)	2.8 (10)	0.9 (17)	0 ---	0 ---	9.6 (131)
Greasewood/shrubs 1	2.2 (34)	1.2 (28)	8.4 (31)	1.5 (27)	0 ---	0 ---	13.3 (119)
Grass	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---
New agriculture	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---
Old Agriculture	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---
Canyon	2.9 (30)	1.2 (27)	8.0 (29)	0.7 (12)	5.4 (92)	1.0 (27)	19.2 (218)
Silt hills 3	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---	0 ---

1/ Averaged from sage and shadscale type densities.

2/ Averaged from sage and winterfat type densities.

3/ Estimated from repeated observations.

Table 13. Estimated snake densities (individuals/ha) and biomass (g/ha) by species and cover types as determined from drift fence captures, May-July, 1978.

Species	Number of Captures				Mean Density	Mean Biomass
	Canyon	Shadscale	Sage	Winterfat		
Striped Whipsnake	38	10	4	2	0.87	96
Gopher Snake	37	10	3	1	2.8	589
Night Snake	16	7	0	0	2.28	32
Racer	11	0	1	0	0.14	11
Western Rattlesnake	5	0	0	0	0.60	242
Western Ground Snake	3	0	0	0	1.14	9
Long-nosed Snake	0	3	0	0	0.47	25
Total Captures;	110	30	8	3		
Estimated Density (n/ha)	13.05	9.45	0.8	0.3		
Estimated Biomass (g/ha)	1715	674	147	53		

Like lizards, snakes were most abundant in the canyon cover type. Shadscale habitats hosted moderate snake populations. Few snakes inhabited sage or winterfat associations (Table 13). Snake densities ranged from 0.3/ha in winterfat to 13.05/ha in the canyon. Both rattlesnakes and whipsnakes showed strong preferences for rocky substrates.

Relative abundance of the more mobile snakes like the nightsnake may be overestimated using drift fences, while sedentary species like the rattlesnake may be underestimated. Mark-recapture studies of rattlesnakes in the canyon yielded density estimates of 4.5/ha to 6.6/ha. A removal census along a stretch of canyon rim in 1976 indicated 11 rattlesnakes per ha.

THE RAPTORS

METHODS OF STUDY: RAPTORS

Nesting Density

Golden eagle populations in both the BPSA and Comparison Area were surveyed each breeding season from 1970 to 1978. Intensive searches for other breeding raptors began in 1973 and continued through 1978. The Idaho Cooperative Wildlife Research Unit provided raw data on food habits and reproductive performance of golden eagles from 1970-71 (Kochert 1972). Locations of nesting prairie falcons in the BPNA from 1970-72 and locations of nesting eagles in the entire area during 1968 and 1969 were obtained from the Idaho Cooperative Wildlife Research Unit (Beecham 1970, Ogden 1973). The U.S. Fish and Wildlife Service provided information on eagle nest locations in the area for 1966-67 (Hickman 1968). BLM surveys in 1973 and 1974 emphasized the BPNA, but searches from 1975 through 1978 covered the entire BPSA. The Comparison Area was fully surveyed for all species in 1977 and 1978. Most surveys were conducted on foot and by boat, but fixed-wing and rotary-wing aircraft were used occasionally from 1970-74. All potential nesting cliffs within the survey area were checked for occupancy. Occupied sites were located on the basis of territorial activity, courtship, brood-rearing activity, presence of young, eggs, or conspicuous field sign (fresh whitewash or new nesting material).

Any area of cliff or group of nests used in one or more years by a mated pair of raptors was considered a "traditional site." A site was called "vacant" if no adults were seen at a previously used site during the breeding season, or if an adult with no apparent attachment to the nesting territory was observed. A "one-bird site" was one where repeated observations indicated a lone adult bird but no breeding attempt. An "occupied site" was any site where there was behavior associated with reproduction exhibited by one or more adult raptors (a "pair") at any time during the breeding season. Presence of a mated pair of birds or field sign (roosts, perches, decorated nests, etc.) indicating occupancy by a pair was sufficient to establish occupancy for buteo and eagle sites. Percent occupancy was calculated only from traditional sites that were selected for study prior to the breeding season (preselected sites).

Home Ranges

Fourteen adult prairie falcons, 8 adult red-tailed hawks and 5 adult golden eagles were captured and fitted with radio transmitters from 1975 through 1977. Falcons and hawks were tagged with 14-24 g back package transmitters (Dunstan 1972, 1977). Eagles were tagged with 180 g back sack radio packages (Craighead and Dunstan 1976, Dunstan 1977). Transmitter components were supplied by AVM Co., Champagne, Ill., and were modified according to the circuitry described by Cochran (1967). Each radio-equipped bird was tracked for a minimum of 44 hours during the breeding season. Some individuals were tracked for as many as 400 hours. In addition, 6 unmarked adult golden eagles were visually observed for range use in 1976 and 1977.

Subjects were tracked primarily from a truck equipped with 220 Mhz receiving units and 11-element Yagi receiving antennas. Aircraft and hand-held portable receivers were used occasionally. Most hawks and eagles were easily observed for extended periods from selected observation points. It was necessary to follow the long flights of falcons by driving on rough dirt trails. Locations were noted whenever birds crossed geographic landmarks (trails, buttes, fields). The outermost distance of a flight was determined by observing the bird at the most distant location or by utilizing telemetry signals when the birds were out of view.

Locations and flight paths of study birds were recorded in narrative form and plotted on 1:125,000 scale maps. Home range was determined by a method similar to the "modified minimum area method" (Harvey and Barbour 1965). Flight paths and perimeter locations were connected to include all areas flown over during the incubation, brood-rearing, and post-fledging periods. This is not to be confused with the "minimum area method" (Mohr 1947), in which the extreme outermost points are connected to form a home range polygon; the latter would include areas where the birds probably did not fly.

Sizes of areas determined by these methods are influenced by sample size; within limits, a greater number of plotted locations will yield a greater area (Odum and Kuenzler 1955, Fuller 1979). Thus, with a small number of locations, the maximum area flown over by a bird can be underestimated. Conversely, a bird may not use all the area within its home range, so the "utilized" area (Odum and Kuenzler 1955) will be smaller. Considering both biases, the ranges presented in this study are probably realistic representations of the areas regularly flown over by raptors. The present study collected no quantitative information on utilized ranges or habitat use; the emphasis in this report is on distances flown from the canyon by the three most conspicuous and widely ranging raptorial species. Individual wandering flights were excluded from the analysis.

Reproductive Performance

Selected nest sites were entered and examined for eggs, eggshell fragments, or other signs of reproductive activity. Nests were not visited during inclement weather or immediately after hatching in order to prevent nest desertion or temperature stress to eggs or young.

Pairs that occupied preselected sites but showed no evidence of egg laying after repeated observations were categorized as "non-breeding." A "breeding attempt" was confirmed if an occupied site contained an incubating adult, eggs, young, or any field sign that indicated eggs were laid, such as fresh eggshell fragments in fresh nesting material. A "successful nesting attempt" was a breeding attempt that produced one or more young that reached fledging age. Young were considered fledged if they reached 80% of the average age at which most young leave the nest of their own volition. Fledging ages were established by observing chicks of known age. Active eagle and buteo nests discovered after young had fledged

were considered successful if (1) a platform decorated that season was worn flat and contained fresh prey remains; (2) fresh fecal matter covered the back and extended over the edge of the nest; and (3) no dead young birds were found within a 50-m radius of the nest. Renesting attempts were considered separate new attempts in calculating productivity.

Because of the large number of nesting raptor pairs, it was impossible to collect complete information at all sites. Consequently, sample sizes for each productivity parameter differ. Percent breeding and percent of pairs successful were tabulated only from preselected sites. Number of successful nestings, number hatched, and number fledged per breeding attempt were tabulated from the preselected sites and additional sites found before or during the incubation phase. Sites discovered after incubation were not used because successful pairs were more easily located than the less conspicuous non-breeders and breeders that failed early, and their inclusion would have biased results in favor of successful sites.

Number of young fledged per pair in the BPSA was estimated using the formula:

$$y = \frac{\left(\frac{(b)}{(n)}\right)\left(\frac{(c)}{(d)}\right)\left(\frac{\sum_{i=1}^{e} f_i}{e}\right)(n)}{(n + x)}$$

where: y = number of young fledged per pair
b = number of preselected breeders
n = number of preselected pairs where breeding vs non-breeding was ascertained
c = number of successful attempts
d = number of breeding attempts where the outcome was known
e = number of successful attempts with complete fledge counts
f_i = the number of young fledged from the ith successful nest
x = the number of unsuccessful preselected pairs in which breeding vs non-breeding was not ascertained.

Total number fledged was obtained by multiplying the above result (y) by the total number of occupied sites. This method maximizes the amount of data utilized by using the small sample of preselected sites to calculate percent breeding $\left(\frac{(b)}{(c)}\right)$, a larger sample of sites found during incubation to calculate percent success $\left(\frac{(c)}{(d)}\right)$ and all successful sites where young were counted to calculate mean number fledged per successful nest $\left(\frac{\sum_{i=1}^{e} f}{e}\right)$. The equation incorporates an adjustment to account for preselected sites (x) where it was not clear if nonbreeding or unsuccessful breeding caused the pair to produce no young.

Sites where investigator manipulations (fostering, shade devices, disease treatment, observation blinds, radio-tracking, and parasite treatment) may have influenced nesting success were excluded from the

productivity analysis. Hatchability (percent of eggs that hatch) was reported only for those sites where both clutch size and brood size at hatching were known. Similarly, nestling survival was calculated only from sites where both brood size at hatching and number fledged were known.

Food Habits

Prey remains and regurgitated pellets were systematically collected from golden eagle, prairie falcon, red-tailed hawk, and raven nests from 1971 to 1978. Prey remains and pellets were collected from each nest every 4-6 days during the brood rearing period in 1971-74 and every fourth day in 1975-78. Fresh remains were identified, marked by removing the head, feet, and tail, and left in the nest. Inedible remains and pellets were collected and analyzed in the laboratory.

Species, size, and sex of prey items were ascertained by comparison with study skins and taxonomic keys. A weight value was assigned to each species-age-sex class for computing biomass (Appendix B).

Prey numbers in the castings were calculated from a maximum count of body parts (femurs, toe-nails, feet, and/or mandibles). Prey remains identified in regurgitated pellets were compared with the tally of fresh prey individuals and partially eaten prey identified during the previous collection. If it was likely that the remains in the pellet were formed from a prey individual that had already been counted, the duplicate was excluded from totals.

During 1977 and 1978, 5 golden eagle, 6 prairie falcon, and 5 red-tailed hawk nests were observed from blinds to supplement prey collections from nests. Because the blind observations showed the same relative proportions of prey as the collections, only the collection results are presented in this report. It was assumed in the analysis that adult and nestling food habits during the nesting season were the same.

RESULTS: RAPTORS

Raptor Density

Nesting Density and Distribution. Fifteen species of birds of prey (including ravens and vultures) nested in the BPSA from 1975 to 1978. Prairie falcons were the most numerous, with a maximum of 209 pairs in 1977 (Table 14). As many as 34 golden eagle, 62 red-tailed hawk, 44 American kestrel, 19 ferruginous hawk, 23 marsh hawk, 20 great horned owl, 69 barn owl, 9 long-eared owl, 18 burrowing owl, and 128 raven pairs nested within the BPSA in any one year. Swainson's hawks, screech owls, short-eared owls, and turkey vultures also nested within the BPSA (Table 14). Counts of marsh hawks, kestrels, and owls were probably incomplete during all four years. If all species were at their maximum observed density in any given year, the total BPSA raptor and raven population would be 646 pairs.

Average distances between nearest adjacent pairs of the same species along the canyon ranged from 647 m for prairie falcons to 6,562 m for ferruginous hawks (Table 15). Adjacent red-tailed hawk nests were an

Table 14. Number of occupied raptor and raven sites recorded in the BPNA and BPSA, 1975-78.

	BPNA				BPSA			
Species	1975	1976	1977	1978	1975	1976	1977	1978
Prairie Falcon	114	129	126	116	186	207	209	183
Golden Eagle	11	11	11	11	32	34	33	32
Red-tailed Hawk	27	25	30	26	50	57	62	59
Kestrel	12	11	17	17	24	25	44	44
Ferruginous Hawk	6	5	6	5	8	14	19	18
Marsh Hawk	4	10	9	10	8	21	23	23
Swainson's Hawk	0	0	0	0	0	1	1	1
Great Horned Owl	10	8	9	5	14	15	18	20
Barn Owl	3	4	10	7	8	13	40	69
Screech Owl	1	2	3	1	1	2	6	3
Long-eared Owl	1	2	2	5	1	2	3	9
Burrowing Owl	0	0	0	2	2	9	10	18
Short-eared Owl	0	0	0	0	0	0	0	2
Turkey Vulture	0	1	1	1	0	1	1	2
Common Raven	50	46	56	51	99	114	120	128
	239	254	280	257	433	515	589	611

Table 15. Average distances (m) between nearest adjacent pairs of the same species in the canyon portion of the BPSA, 1971-78. Minima and maxima are shown in parentheses.

	Golden Eagle	Prairie Falcon	Red-tailed Hawk	Ferruginous Hawk
1971	3371 (1154-8346)	--	--	--
1972	3454 (1177-5366)	--	--	--
1973	3282 (1459-8295)	--	--	--
1974	3371 (1834-8297)	--	--	--
1975	3271 (1980-7738)	663 (108-4251)	1893 (345-6241)	9335 (2257-16,824)
1976	3477 (1029-8164)	627 (82-6658)	2241 (700-8234)	5420 (1232-24,987)
1977	3638 (968-7864)	637 (90-4339)	1958 (426-5315)	5664 (1232-24,364)
1978	3936 (2271-8346)	659 (134-4183)	2239 (725-7668)	5829 (1359-24,509)
Average	3475	647	2083	6562

average of 2,083 m apart, and an average of 3,475 m separated occupied golden eagle nests. The closest occupied prairie falcon nests were 83 m apart. The minimum distance between red-tailed hawk eyries was 345 m. Eagle pairs never nested closer than 968 m to another pair.

The BPNA hosted more nesting raptors than any other portion of the river (Fig. 14). The cliffs along the 50 km of river between Halverson Lake and Black Butte had nearly twice as many raptors (290) as any other 50-km section. Birds of prey were most numerous in the 30 km between Halverson Lake and Wild Horse Butte.

Raptor density in the Comparison Area upstream from Hammett was considerably lower than in the BPSA. Only 28 pairs of prairie falcons, red-tailed hawk, and golden eagles were found in the 80 km stretch between Hammett and Bliss in 1978. Average minimum distances between pairs in the area from Bliss to Hammett were 3,691 m for prairie falcons, 3,804 m for red-tailed hawks, and 3,287 m for golden eagles in 1978. Similarly, raptor density was markedly lower downstream from Walters Ferry, the west end of the BPSA.

Prairie falcons accounted for most of the local variation in density. Red-tailed hawks and golden eagles were evenly spaced throughout the BPSA and Comparison Area. Prairie falcons, on the other hand, were concentrated in certain areas. Prairie falcon densities were highest between Halverson Lake and Wildhorse Butte and intermediate between Grand View and Bruneau. East of Hammett only five prairie falcon pairs nested (Fig. 14).

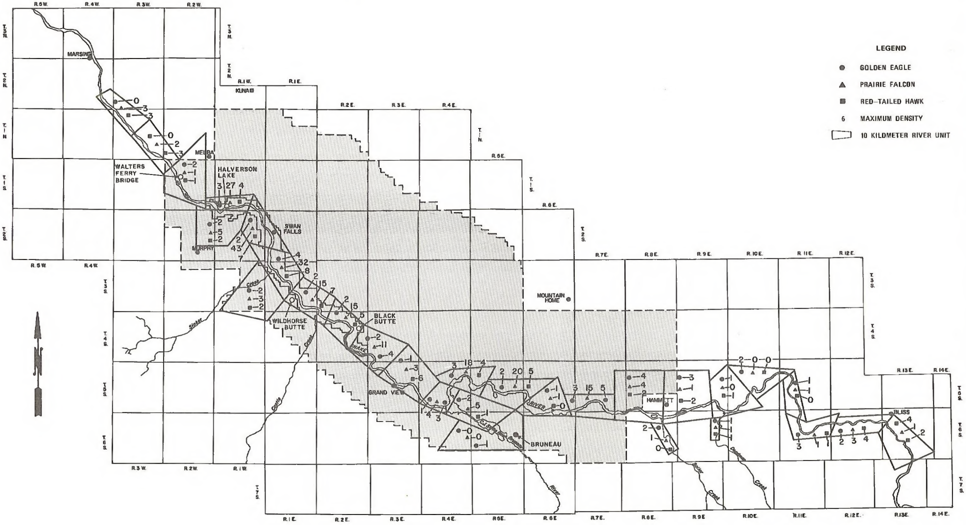
Eagle numbers varied only slightly during the 4 year period (Table 14). The number of prairie falcon and red-tailed hawk pairs in the BPSA was lowest in 1975 and highest in 1977 (Table 14). The apparent increase in pairs from 1975 to 1976 may be an artifact of research procedure due to the researchers' unfamiliarity with the locations of traditional nesting sites in 1975. The number of prairie falcon pairs dropped from 209 in 1977 to 183 in 1978, a decrease of 12%. Red-tailed hawk pairs declined from 62 to 59 during the same period. Counts within the BPNA reflected the same general yearly trends as surveys of the entire BPSA.

Occupancy. The proportion of traditional sites occupied by eagles declined from 1975 to 1978 (Table 16). Prairie falcons occupied an average of 90.5% of all preselected traditional sites in 1975 and 1976, but after the drought the occupancy rate dropped to an average of 76.5% in 1977 and 1978. Despite the sizeable increase in vacant traditional sites, the total number of falcon pairs located in 1977 increased slightly from 1976, apparently due to the formation of new territories. This may have been a result of birds shifting from one site to another. It is also possible that counts of prairie falcons in 1975 and 1976 were incomplete. Red-tailed hawks occupied between 83 and 97% of preselected traditional territories from 1974 to 1978. More sites were vacant in 1976 and 1978 than in the other years (Table 16).

Non-nesting Raptors. In addition to the population of raptors occupying nesting sites, numerous subadult and adult raptors not associated with a nesting territory inhabit the BPSA during the breeding season. It is difficult to accurately census these "floaters" (Brown 1969), but frequent sightings of territorial confrontations between es-

Fig. 14. Maximum yearly nesting densities of the three major raptor species in the BPSA and Comparison Area.

Densities of raptors were highest in the three river units between Halverson Lake and Wildhorse Butte. Few prairie falcons nested upstream (east) from Hammett or downstream from Walter's Ferry Bridge. Only one river unit contained more than 3 nesting pairs of golden eagles, but as many as 43 prairie falcon pairs nested along a 10 km section of river. The numbers shown on the map represent the maximum number of pairs observed in a particular 10 km river unit in any year.



MAXIMUM YEARLY NESTING DENSITIES OF THE THREE MAJOR RAPTOR SPECIES IN THE BPSA AND COMPARISON AREA

Table 16. Percent of preselected traditional sites in the BPSA occupied by raptors, 1971-78. Number of traditional sites sampled in parentheses.

	Golden Eagle	Prairie Falcon	Red-tailed Hawk	Ferruginous Hawk
1971	100% (34)	---	---	---
1973	100% (34)	---	---	---
1974	100% (34)	---	96% (25)	83% (10)
1975	94% (34)	97% (29)	93% (27)	80% (10)
1976	97% (34)	84% (31)	83% (29)	60% (10)
1977	94% (34)	77% (31)	94% (31)	83% (18)
1978	89% (36)	76% (41)	83% (42)	72% (18)

tablished pairs and birds not associated with a territory confirm their presence. Both adults and immatures comprise the floating population. Three adult golden eagles trapped in the BPSA in 1977 showed no attachment to a nesting territory. During the 1971 breeding season, 46 of 73 (63%) golden eagles sighted more than 3.2 km from the canyon were in subadult plumage. Non-nesting red-tailed hawks in subadult plumage are also seen frequently.

The rapidity with which new individuals enter the nesting population suggests that floaters in the BPSA may be numerous. Two golden eagles and one red-tailed hawk are known to have acquired new mates within a month of their previous mate's death.

Raptor Home Ranges

Golden Eagles. Boundaries of most adjacent eagle home ranges were contiguous but some overlapped slightly (Figs. 15 and 16). Eagles defended their home ranges. Exclusive territories have been reported for golden eagles and other *Aquila* species in other areas (Dixon 1937, Brown and Watson 1964, Gargett 1975, Lockhart pers. comm.).

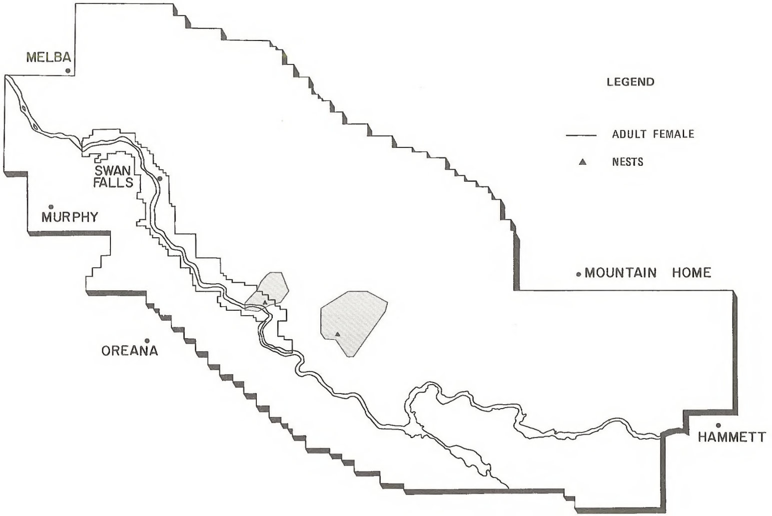
Because there was little difference in range sizes of breeding and non-breeding eagles, the range sizes of both were used in the analysis. Home ranges of individual golden eagles varied from 5 to 43 km^2 and averaged 16 km^2 (Appendix C). Maximum distances from the nest flown by individual eagles ranged from 4 to 15 km and averaged 7 km. Home ranges for 5 pairs ranged from 5 to 49 km^2 and averaged 22 km^2. Eagle home ranges averaged 5 km wide along the canyon (Table 17; Appendix C). Although the radioed birds did not show extensive use of the south side of the river, unmarked birds associated with certain nest sites were repeatedly observed foraging on the south side. Since the average distance between nearest adjacent eagle pairs is only 3.5 km, and the average width of eagle home ranges is 5 km, it is reasonable to assume that certain pairs forage primarily on the south side and the remainder hunt north of the river.

Prairie Falcons. In contrast to golden eagles, prairie falcons had large, elongated home ranges running in a general northeasterly direction. Unlike eagles, adjacent pairs of prairie falcons exhibited a large degree of overlap in home ranges (Figs. 17, 18, and 19), as has been observed in prairie falcons by other researchers (Newton 1976). Individual prairie falcon home range sizes varied from 26 to 142 km^2 with a mean of 76 km^2 (Appendix D). Individuals flew a maximum of 26 km from the nest and 30 km from the river, with means of 19 and 21 km, respectively. The mean home range utilized by seven pairs was 121 km^2, and pair ranges varied from 87 to 162 km^2 (Table 17). Pairs flew a mean maximum of 22 km from the nest and 24 km from the river, with maxima of 26 and 30 km, respectively.

Except for one pair at the eastern boundary of the BPSA, all ranges of radioed prairie falcons were exclusively north of the river (Figs. 17, 18 and 19). Most falcon flights were roughly perpendicular to the river; the longest axes of individual prairie falcon ranges had a mean angle of 77^o from the river. A chi-square test indicated that this pattern was significantly different from random directions of flight ($\chi^2 = 53$, df =

Fig. 15. Home ranges of radioed golden eagles in the BPSA, 1976.

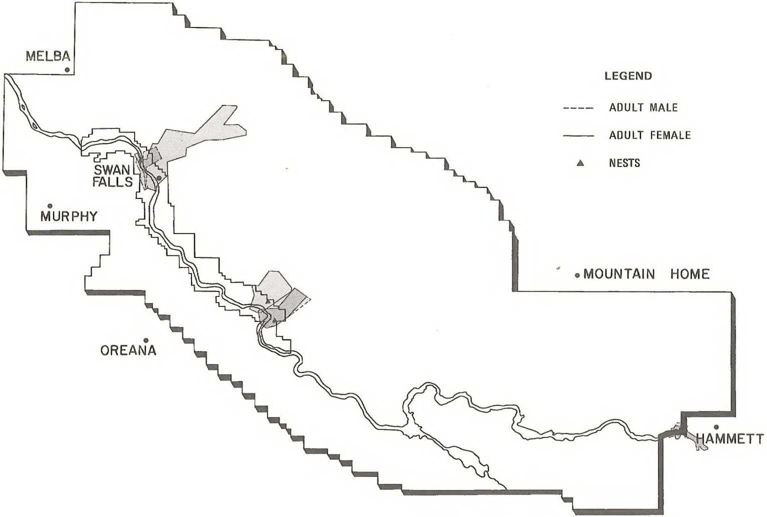
Golden eagles flew a maximum of 7 km from the nest during the breeding season and had home ranges that averaged 22 km^2.



HOME RANGES OF RADIOED GOLDEN EAGLES IN THE BPSA, 1976

Fig. 16. Home ranges of radioed golden eagles in the BPSA, 1977.

Eagles were territorial and had contiguous ranges. The ranges of breeding and non-breeding eagles were similar in size. The two ranges shown in the middle of the BPSA represent a breeding pair and a non-breeding female. The ranges near Swan Falls are those of a pair whose nesting attempt failed during incubation.



HOME RANGES OF RADIOED GOLDEN EAGLES IN THE BPSA, 1977

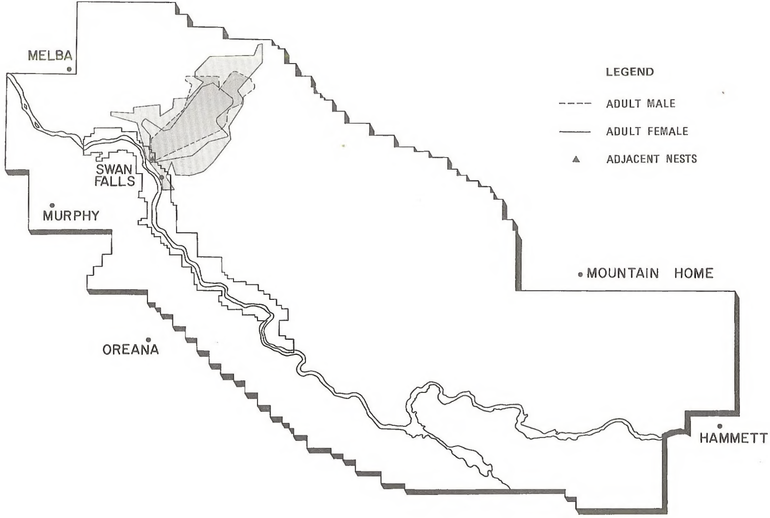
Table 17. Summary of mean home range characteristics for golden eagle, red-tailed hawk, and prairie falcon pairs in the BPSA, 1975-77.

	Home Range (km^2)	Max. Dist. from Nest (km)	Max. Length of Home Range* (km)	Max. Width of Range along Canyon (km)
Golden eagle				
1976	35	7	9	6
1977	13	5	7	4
MEAN	22	6	7	5
Prairie falcon				
1975	144	21	22	14
1976	130	25	27	14
1977	96	19	19	11
MEAN	121	22	24	13
Red-tailed Hawk				
1976	13	5	6	5
1977	16	5	6	5
MEAN	15	5	6	5

* Maximum distance from river for prairie falcons.

Fig. 17. Home ranges of radioed prairie falcons in the BPSA, 1975.

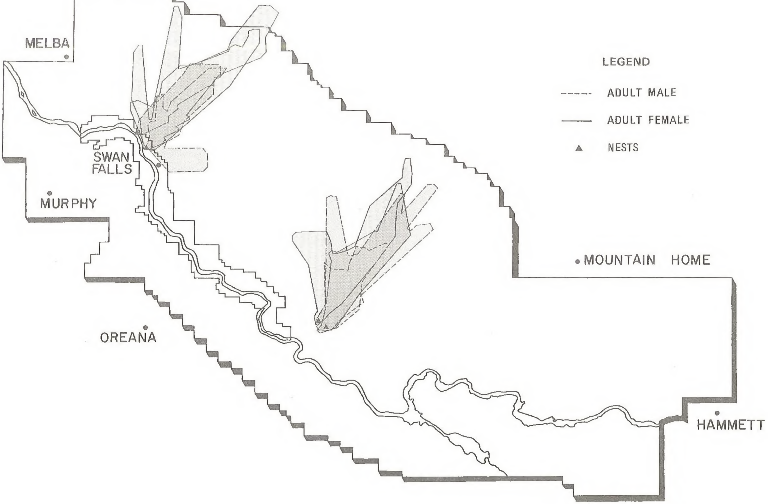
Prairie falcon home ranges averaged 121 km^2. Falcons flew a maximum of 27 km from the river, and maximum width of the home range along the canyon was 13 km.



HOME RANGES OF RADIOED PRAIRIE FALCONS IN THE BPSA, 1975

Fig. 18. Home ranges of radioed prairie falcons in the BPSA, 1976.

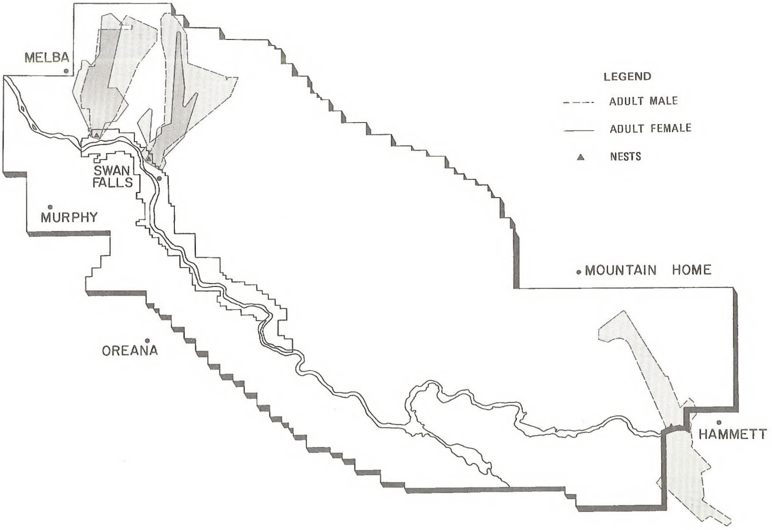
Prairie falcons in the BPSA have large, elongated home ranges running in a general northeasterly direction. Unlike eagles, adjacent pairs of prairie falcons exhibited a large degree of overlap, although they did defend a small area around their nests.



HOME RANGES OF RADIOED PRAIRIE FALCONS IN THE BPSA, 1976

Fig. 19. Home ranges of radioed prairie falcons in the BPSA, 1977.

Four reasons for the large home range size of prairie falcons are: 1) their characteristic hunting style which requires large, open spaces; 2) their dependence on a single important prey item; 3) the uneven distribution of that prey item; and 4) intra- and interspecific competition.



HOME RANGES OF RADIOED PRAIRIE FALCONS IN THE BPSA, 1977

7, $P < .001$). Ranges of falcon pairs had a mean angle of flight from the river of 80.1^{o}, also significantly different from random orientation ($\chi^2 = 26$, df = 7, $P < 0.001$).

Red-tailed Hawks. Like eagles, red-tailed hawk pairs were territorial and defended both the nesting area and the home range. Observations of territorial interactions between radioed and neighboring unmarked birds indicated that ranges of adjacent pairs were contiguous. These characteristics have been reported for red-tailed hawks and other buteos elsewhere (Fitch et al. 1946; Craighead and Craighead 1956; Picozzi and Weir 1974).

Individual red-tailed hawks used home ranges from 1 to 27 km^2 with a mean area of 15 km^2 (Appendix E). Males generally had larger home ranges than females. In some cases, the home range of a female was totally encompassed by that of the male (Figs. 20, 21 and 22). Maximum distance flown from the nest ranged from 1 to 8 km ($\overline{x}$ = 5 km). Red-tailed hawk pairs used home ranges of 11 to 22 km^2 ($\overline{x}$ = 15 km^2) and flew a mean maximum distance from the nest of 5 km (Table 17).

<u>Raptor Reproductive Performance</u>

Golden Eagles. Non-breeding eagle pairs comprised 0 to 44% of the total number of pairs occupying territories from 1971 to 1978 (Table 18). Non-breeding was highest in 1973 and lowest in 1971. Average clutch size was 1.98 during the study. No three egg clutches were observed from 1973 through 1976.

Hatchability at sites where both clutch size and number hatched were known was 69%. Eighty-four cases of egg losses were recorded. Fifteen eggs examined were infertile, 3 embryos died during normal incubation, and 37 died after adults abandoned the nesting attempt. Two eggs were lost due to human disturbance, and a cause of loss could not be ascribed to 27 eggs.

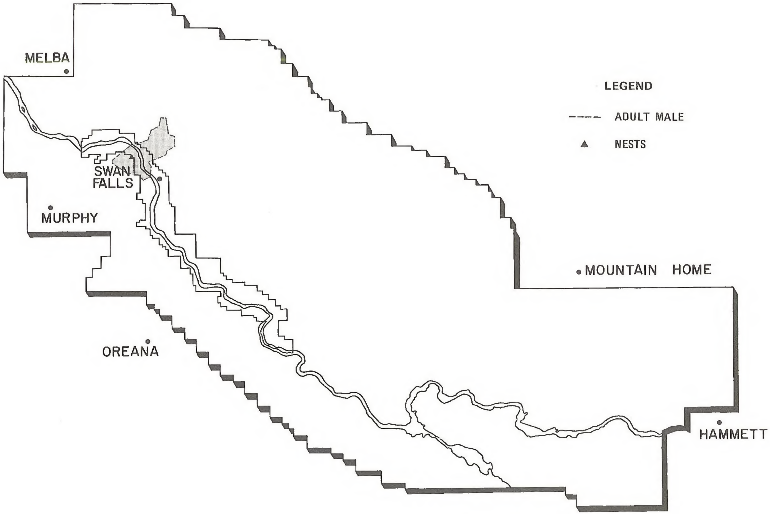
The number of hatchlings per breeding attempt ranged from 1.14 to 2.67 and averaged 1.40 (Table 18). Among nests that hatched young, the brood size at hatching was relatively constant and averaged 1.77 for all years combined.

Nestling survivorship at 111 nests averaged 71%. The 45% nestling survival for 11 sample nests in 1977 may have been an artifact of sampling. Considering the other reproductive parameters for that year (Table 18), number fledged per attempt divided by number hatched per attempt (1.16/1.59 = 73%) may be a more realistic measure of nestling survival. One hundred five cases of nestling losses were recorded. Of the 50 nestling mortalities where cause of death was known, 21 were due to heat stress, 15 were due to trichomoniasis, and 8 were due to direct human disturbance (including shooting). Two young eagles fell from the nest and died, and 4 deaths were attributed to fratricide.

From 1971 to 1978, 30-61% of pairs occupying traditional sites produced young that reached fledging age. Of all breeding attempts 57-74% produced fledging young in those years (Table 18). The small sample

Fig. 20. Home ranges of radioed red-tailed hawks in the BPSA, 1975.

Red-tailed hawks flew a maximum of 5 km from the nest. Ranges of red-tailed hawks in the BPSA averaged 15 km^2.



HOME RANGES OF RADIOED RED-TAILED HAWKS IN THE BPSA, 1975

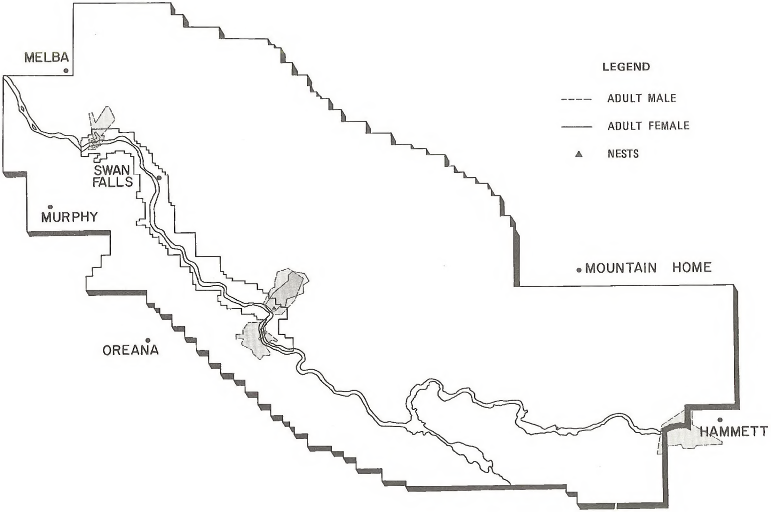
Fig. 21. Home ranges of radioed red-tailed hawks in the BPSA, 1976.

Like eagles, red-tailed hawk pairs were territorial and defended both the nesting area and the home range. With an average home range width of 5 km and an average distance between nearest adjacent pairs of only 2.1 km, it is reasonable to assume that roughly half of the red-tailed hawks hunt north of the river and half hunt on the south side.

HOME RANGES OF RADIOED RED–TAILED HAWKS IN THE BPSA, 1976

Fig. 22. Home ranges of radioed red-tailed hawks in the BPSA, 1977.

The home ranges of female red-tailed hawks were sometimes totally encompassed by those of the males.



HOME RANGES OF RADIOED RED–TAILED HAWKS IN THE BPSA, 1977

Table 18. Golden eagle reproductive parameters in the BPSA and Comparison Area, 1970-78.*
(sample sizes in parentheses)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	Pooled Mean
Percent Breeding	-- --	100% (54)	-- --	56% (55)	62% (50)	78% (50)	70% (53)	84% (51)	75% (52)	75.0% (365)
Clutch Size	1.95 (19)	2.12 (33)	2.75 (4)	1.88 (17)	1.80 (15)	1.94 (16)	1.73 (11)	1.91 (11)	2.11 (9)	1.98 (135)
Hatchability	65% (19)	57% (30)	100% (3)	72% (15)	70% (11)	74% (16)	56% (9)	87% (8)	91% (6)	69% (117)
Hatchlings Per Attempt	1.20 (20)	1.14 (35)	2.67 (3)	1.45 (20)	1.42 (19)	1.44 (18)	1.29 (14)	1.59 (17)	1.81 (16)	1.40 (162)
Mean Brood Size at Hatching	1.67 (18)	1.74 (23)	2.67 (3)	1.71 (17)	1.69 (16)	1.73 (15)	1.64 (11)	1.80 (15)	2.07 (14)	1.77 (132)
Nestling Survival	86% (17)	83% (21)	100% (3)	59% (17)	64% (15)	61% (13)	83% (4)	45% (11)	75% (10)	71.0% (111)
# Fledged Per Pair	--	1.07	--	0.43	0.56	0.65	0.63	0.96	0.94	0.75
# Fledged Per Attempt	1.06 (18)	1.04 (49)	2.25 (4)	0.80 (30)	1.00 (28)	0.85 (34)	0.97 (29)	1.16 (31)	1.24 (29)	1.03 (252)
# Fledged Per Successful Attempt	1.77 (26)	1.75 (32)	1.64 (22)	1.41 (17)	1.53 (19)	1.38 (21)	1.47 (19)	1.71 (21)	1.76 (21)	1.62 (198)
% of Pairs Successful	-- --	61% (51)	-- --	30% (56)	35% (54)	46% (48)	40% (50)	53% (43)	51% (47)	44.6% (349)
% of Attempts Successful	68% (19)	61% (51)	100% (4)	57% (30)	66% (29)	63% (35)	67% (30)	71% (35)	74% (34)	65.9% (267)

* Does not include data from sites where investigator manipulations (disease treatment, fostering, observation blinds, radio-tagging etc.) may have affected the parameter in question.

of 4 successful breeders in 1972 cannot be considered representative of the population. Overall, of 234 eggs monitored through the nesting period, 110 (47%) developed into fledging-age young. Eagles fledged an average of 0.75 young per pair, 1.03 young per attempt, and 1.62 young per successful attempt during the 9 years of study. This productivity level is similar to that reported by long term research in other areas (Brown 1974, Murphy 1975). The total number of young fledged in the BPSA ranged from 14 in 1973 to 41 in 1971.

Prairie Falcons. Non-breeding prairie falcon pairs comprised 4 to 13% of the total number of pairs occupying preselected traditional territories from 1974 to 1978 (Table 19). Percent breeding was lowest in 1977.

Clutch size averaged 4.46 and varied little from 1974 through 1978. Clutch sizes in 1971 and 1972 were similar, averaging 4.3 and 4.5, respectively (Ogden and Hornocker 1977). Hatchability at sites where both clutch size and number hatched were known was 79%. One hundred seventeen egg losses were recorded, 74 of which could not be assigned causes. Nest abandonment was responsible for 28 eggs lost, and 2 others were lost after the death of the adult bird. At least 1 egg was infertile, 8 embryos died during normal incubation, and predators destroyed 4 eggs.

The number of hatchlings per breeding attempt ranged from 3.11 to 3.74 and averaged 3.46 (Table 19). Among nests that hatched young, brood size at hatching averaged 3.93 for all years combined. Nestling survival at 86 nests averaged 77%, and 147 cases of nestling losses were recorded. Nine young prairie falcons fell from the nest and died before fledging, 4 died of heat stress, and 4 died when their parents abandoned the nest. Predators were responsible for the deaths of at least 9 nestlings, cannibalism for 1, and human disturbance for 1. One nestling starved and causes could not be ascribed to 118 nestling losses. Nestling survival was distinctly lower in 1977 and 1978.

In 1974-76, 71-77% of preselected pairs produced young that fledged, while only 45-50% fledged young in 1977-78. During pre-drought years, 75-87% of all breeding pairs sampled early in the season produced fledging young, compared with 59-69% in post-drought years (Table 19).

Prairie falcons in the BPSA fledged an average of 2.5 young per pair, 2.67 young per attempt, and 3.89 young per successful attempt during the 5 years of study. Values for all parameters were considerably lower in 1977 and 1978 (Table 19). The total number of young fledged in the BPSA ranged from 289 in 1978 to 631 in 1976 (Table 19). Of 358 eggs observed through the entire development period, 193 (54%) developed into fledging age young.

Red-tailed Hawks. Non-breeding red-tailed hawk pairs comprised 4-19% of the total number of pairs occupying traditional territories within the BPSA from 1973 to 1978 (Table 20).

Table 19. Prairie falcon reproductive parameters in the BPSA, 1974-78.* Sample sizes in parentheses.

	1974	1975	1976	1977	1978	Pooled Mean
Percent Breeding	94% (16)	92% (24)	96% (24)	87% (23)	96% (25)	93% (112)
% of Attempts Successful	75% (20)	87% (31)	79% (34)	69% (35)	56% (32)	73% (152)
No. Fledged Per Successful Attempt	4.00 (18)	3.83 (29)	4.02 (40)	4.00 (27)	3.52 (23)	3.89 (137)
No. Fledged Per Pair	2.65	2.83	3.05	2.40	1.58	2.50
Total Young Fledged**	----	526	631	502	289	487
Clutch Size	4.40 (10)	4.35 (17)	4.48 (25)	4.68 (28)	4.35 (34)	4.46 (114)
Hatchability	83% (9)	77% (14)	77% (21)	86% (24)	74% (22)	79% (90)
Hatchlings Per Attempt	3.50 (12)	3.61 (18)	3.33 (24)	3.74 (35)	3.11 (27)	3.46 (116)
Mean Brood Size at Hatching	4.00 (13)	3.79 (19)	3.91 (23)	4.03 (39)	3.88 (24)	3.93 (118)
Nestling Survival	80% (12)	94% (17)	84% (19)	64% (24)	67% (14)	77% (86)
No. Fledged Per Attempt	2.69 (16)	3.31 (26)	2.93 (30)	2.59 (32)	1.89 (28)	2.67 (132)
% of Pairs Successful	71% (17)	77% (26)	73% (22)	50% (18)	45% (22)	64% (105)

* Does not include data from sites where investigator manipulations (disease treatment, fostering, observation blinds, radio-tagging etc.) may have affected the parameter in question.

** Based on total number of BPSA pairs reported in Table 14.

Table 20. Red-tailed hawk reproductive parameters in the BPSA, 1973-78.* Sample sizes in parentheses.

	1973	1974	1975	1976	1977	1978	Pooled Mean
Percent Breeding	93% (14)	85% (20)	96% (24)	81% (26)	86% (29)	92% (36)	89% (149)
% of Attempts Successful	57% (14)	63% (19)	65% (23)	67% (24)	52% (29)	77% (31)	64% (140)
No. Fledged Per Successful Attempt	3.12 (8)	2.92 (13)	2.81 (16)	2.73 (15)	2.53 (17)	2.45 (22)	2.70 (91)
No. Fledged Per Pair	1.54	1.36	1.75	1.48	1.13	1.74	1.50
Total Young Fledged**	----	----	88	84	70	102	86
Clutch Size	2.00 (1)	3.00 (11)	3.25 (16)	3.06 (18)	2.95 (19)	2.71 (14)	2.99 (79)
Hatchability	50% (1)	88% (11)	84% (14)	58% (16)	61% (15)	61% (11)	69% (68)
Hatchlings Per Attempt	1.83 (6)	2.57 (14)	2.71 (17)	1.95 (19)	2.00 (21)	1.88 (16)	2.17 (93)
Mean Brood Size at Hatching	2.75 (4)	2.71 (14)	3.07 (15)	3.08 (12)	3.00 (16)	2.46 (13)	2.86 (74)
Nestling Survival	64% (4)	82% (14)	76% (15)	96% (7)	63% (9)	73% (11)	76% (60)
No. Fledged Per Attempt	1.77 (13)	1.89 (19)	1.83 (23)	1.82 (22)	1.19 (27)	1.81 (27)	1.70 (131)
% of Pairs Successful	53% (15)	48% (23)	65% (23)	59% (22)	44% (25)	70% (27)	57% (135)

* Does not include data from sites where investigator manipulations (disease treatment, fostering, observation blinds, radio-tagging etc.) may have affected the parameter in question.

** Based on total number of BPSA pairs reported in Table 14.

Average clutch size was 2.99 with no distinct differences among years. Hatchability at sites where both clutch size and number hatched were known was 69%. At least 13 eggs were destroyed by predators, 14 were abandoned, and 4 were lost after the death of an adult. Weather was responsible for 6 lost eggs and human disturbance accounted for 5.

The number of hatchlings per breeding attempt ranged from 1.83 to 2.71 and averaged 2.17 (Table 20). Among nests that hatched young, the mean brood size at hatching averaged 2.86.

Nestling survivorship at 60 nests averaged 76%, with 1977 nestlings having the lowest survival rate. Eighty-three cases of nestling losses were recorded. Of 42 cases where the cause of nestling mortality was known, 13 were attributed to heat stress, 10 to accidental falls from the nest, 3 to abandonment, 2 to predation, 1 to disease, and 13 nestling mortalities to human disturbance.

From 1973 to 1978, 44-70% of preselected pairs fledged young. In the same years, 52-77% of all breeding pairs sampled early in the season produced fledging young (Table 20). Percent success was lowest in 1977.

Red-tailed hawks fledged an average of 1.5 young per pair, 1.7 young per attempt, and 2.7 young per successful attempt during the 6 years. Both number fledged per pair and number fledged per attempt were notably lower in 1977. The total number of young fledged in the BPSA ranged from 70 in 1977 to 102 in 1978 (Table 20). Of 209 eggs monitored through the entire development period, 100 (48%) developed into fledging age young.

Raptor Food Habits

Golden Eagles. Black-tailed jackrabbits were the most important food item of eagles, both in frequency and biomass, from 1971 to 1978 (Appendix F). Nearly 60% of the biomass consumed by eagles during that period was jackrabbit. Cottontails and ring-necked pheasants ranked second in importance by frequency and biomass respectively.

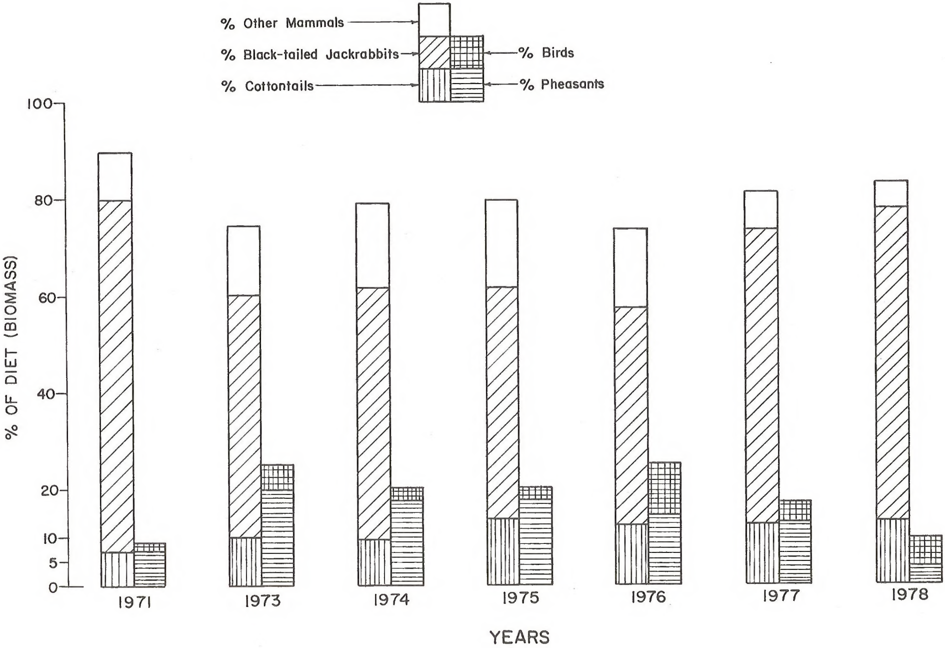
Mammals comprised 81.9% of the biomass in the eagle diet, birds comprised 16.1%, reptiles comprised 0.7%, and fish accounted for 0.9%. Although more than 30 species of birds were identified in eagle nests, avian prey other than pheasants constituted less than 10% of the total numbers of individual prey collected at eagle nests. Pheasants were important in the diet only at nests adjacent to agriculture. The proportion of pheasants in the diet of the collective eagle population declined steadily from 1975 to 1978 (Fig. 23).

From 1971 to 1978, cottontails comprised a relatively constant proportion of the eagle diet, ranging from 15.6 to 23.5% in frequency and 7.2 to 13.8% in biomass (Fig. 23). Jackrabbits, on the other hand, decreased from 73% of the biomass in 1971 to 50 and 52% in 1973 and 1974 and 48 and 45% of the biomass in 1975 and 1976. They then increased to 61 and 65% in 1977 and 1978. Fish appeared in the diet only in 1978.

Prairie Falcons. From 1974 to 1978, Townsend ground squirrels comprised more than 50% of both the prey items and the biomass consumed

Fig. 23. Proportions of the major taxa in the golden eagle diet by year, 1971, 1973-78.

Lagomorphs comprised more than half of the golden eagle diet in all years. While cottontail proportions remained relatively constant, yearly changes in the proportions of jackrabbits reflected yearly changes in jackrabbit densities.



PROPORTIONS OF THE MAJOR TAXA IN THE GOLDEN EAGLE DIET BY YEAR, 1971, 1973–78

by prairie falcons in the BPSA and Comparison Area (Appendix G). Passerines, reptiles, lagomorphs, and other rodents were also taken, but no single species ranked as an important secondary prey in the diet. Passerines ranked second in frequency with 19% of the individuals, but contributed less than 6% of the biomass. Jackrabbits were second most important in biomass, but were represented by only fourteen individuals, compared to 522 ground squirrels.

Like eagles, falcons consumed a large variety of avian species, but birds did not constitute a large part of their diet. Mammals comprised 85.3% of the biomass in the falcon's diet, birds made up 12.7%, and reptiles accounted for 1.5% (Appendix G).

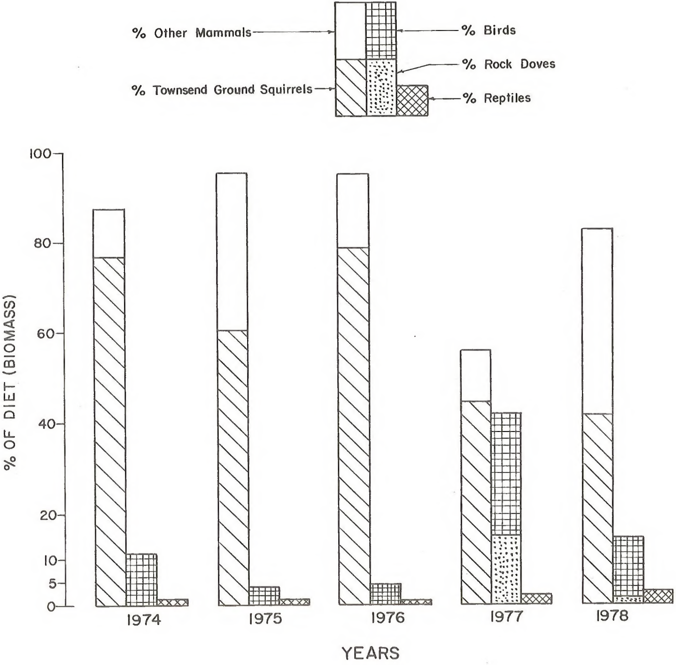
The proportion of ground squirrels in the diet declined substantially when ground squirrel populations declined in 1977, and proportions remained low in 1978 (Fig. 24). In 1977 and 1978, the proportions of both birds and reptiles in the prairie falcon diet increased.

Red-tailed Hawks. Of the three major raptor species, red-tailed hawks were the most generalized predators, feeding on a wide variety of mammals, reptiles, and birds (Appendix H). Townsend ground squirrels, black-tailed jackrabbits, gopher snakes, cottontails, and kangaroo rats each comprised more than 5% of the total number of individual prey items found in collections. Ground squirrels, jackrabbits, and cottontails comprised 68% of the biomass in the red-tailed hawk diet. Ground squirrels were the most important in frequency, but jackrabbits were the most important in biomass.

Mammals comprised 83.5% of biomass in the red-tailed hawk diet, reptiles made up 11.6%, birds comprised 4.2%, and invertebrates and amphibians accounted for 0.1%. Proportions of the main taxa in the diet by year are shown in Fig. 25. While the proportion of mammals stayed relatively constant, jackrabbits increased in the diet when ground squirrels were unavailable in 1977. Ground squirrel biomass in the diet decreased from an average of 47% in 1973-76 to an average of only 7% in 1977-78. During the same time periods, average jackrabbit biomass increased from 5% to 48%.

Fig. 24. Proportions of the major taxa in the prairie falcon diet by year, 1974-78.

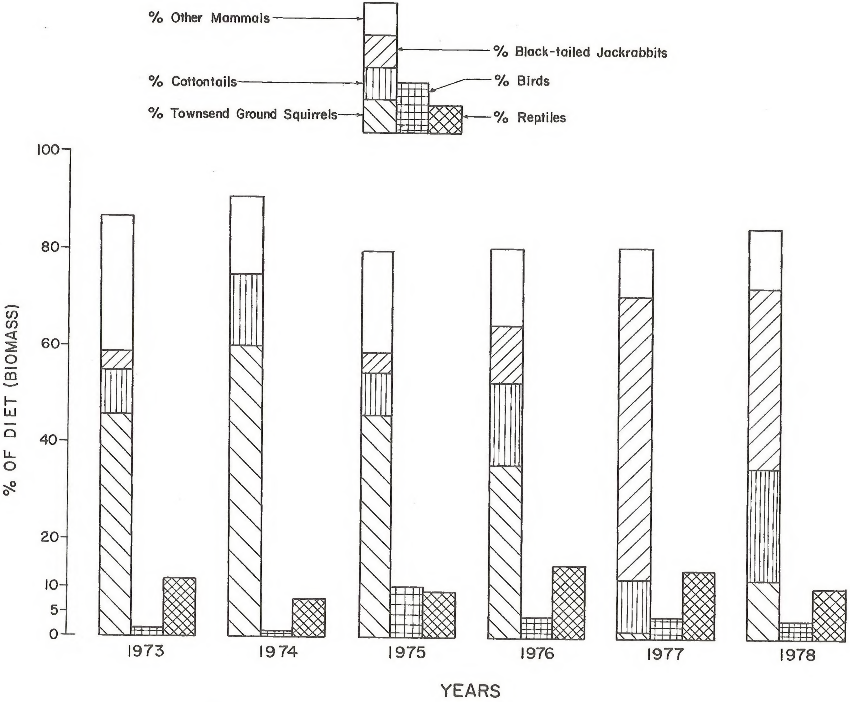
Townsend ground squirrels were the single most important prey species of prairie falcons in all years. The proportion of ground squirrels in the diet declined in 1977-78 when squirrel populations were low. Rock doves increased in the diet in 1977 and jackrabbits increased in 1978.



PROPORTIONS OF THE MAJOR TAXA IN THE PRAIRIE FALCON DIET BY YEAR, 1974–78

Fig. 25. Proportions of the major taxa in the red-tailed hawk diet, 1973–78.

Mammals were the most important group of prey in the red-tailed hawk diet in all years, but the proportion of ground squirrels dropped sharply from 1973-76 to 1977-78. In contrast to prairie falcons, red-tailed hawks were apparently unable to effectively hunt ground squirrels when squirrel populations were low. An increase in black-tailed jack-rabbits apparently compensated for the decreased number of ground squirrels in the diet.



PROPORTIONS OF THE MAJOR TAXA IN THE RED–TAILED HAWK DIET, 1973–78

RAPTOR - PREY INTERACTIONS

THE INFLUENCE OF PREY ON RAPTOR NESTING DENSITY AND DISTRIBUTION

The distribution of nesting raptors in the BPSA and Comparison Area corresponds closely to the distribution of both Townsend ground squirrels and total cliff area. Raptor densities are highest near Swan Falls, where both squirrel numbers and cliff areas are greatest. Upstream and downstream from Swan Falls, raptor density, ground squirrel density, and cliff area all decrease (Figs. 7 and 14).

To assess the relative importance of factors which influence raptor density, series of multiple regressions were run that related raptor density along 30 km river units in the BPSA and Comparison Area to ground squirrel density and cliff characteristics in those stretches.

Ground squirrel density was the most important factor, accounting for more than 87% of the variation in total number of nesting raptor pairs (Table 21). Total cliff area was the next most important variable, accounting for an additional 8% of the variation. The amount of cliff in Category II (7.6-15.1 m high) accounted for another 1%.

Variation in prairie falcon numbers can be explained by the same factors that influence the total number of pairs, with ground squirrels accounting for 86% of the variation and cliff area explaining an additional 10%. Category IV cliff (30.6-60.9 m) was the third most important variable explaining prairie falcon density. The close relationship between prairie falcon and ground squirrel densities can be seen in Fig. 26.

Golden eagle density, on the other hand, was not closely correlated with ground squirrel density (Table 21). Jackrabbit densities were not used in the analysis because there were no apparent differences in jackrabbit density by segment. Total cliff area accounted for 74% of the variation in eagle numbers, and squirrel density explained another 8%. The total amount of variation explained by cliff characteristics and prey, however, was lower for eagles than for prairie falcons and red-tailed hawks. Eagles were distributed fairly evenly throughout the BPSA and Comparison Area, as shown in Fig. 26. This suggests that territoriality is more important in regulating eagle nesting density than local variation of either prey or nest site availability (Brown and Watson 1964).

The amount of cliff area in Category II was the factor explaining most of the variation (90%) in red-tailed hawk density. Ground squirrel density was the second most important factor, accounting for an additional 6%. The simple correlation coefficient between red-tailed hawks and squirrel densities, however, was actually higher than that between prairie falcons and squirrels (Table 21).

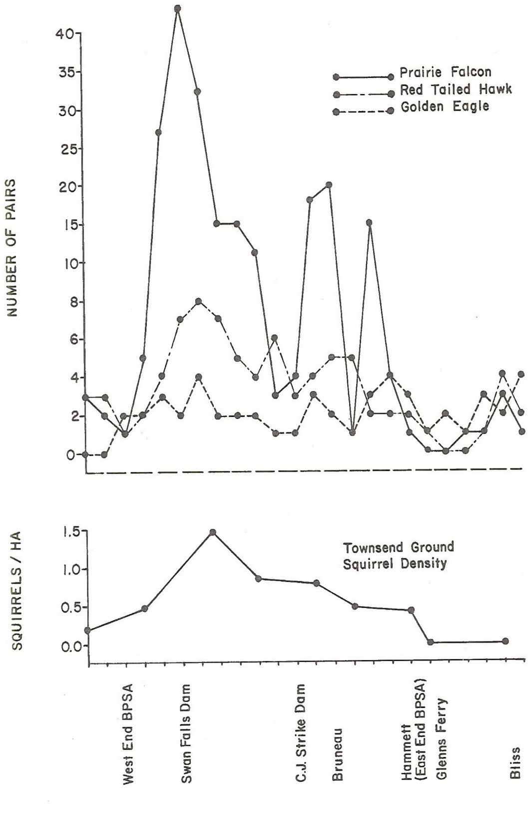
Availability of nest sites is clearly not the sole reason for high densities of all the raptors combined. An average of 0.109 raptor pairs (0.038 prairie falcon pairs) occupies for each km^2 of cliff in the BPSA,

Table 21. Results of multiple regression analysis relating raptor nesting density to ground squirrel density and amount of cliff present.

STEP	VARIABLE	F	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R
Prairie Falcon Pairs							
1	March ground squirrel density	35.42471	.001	.92475	.85516	.85516	.92475
2	Total Cliff Area	10.95419	.021	.97704	.95461	.09945	.88000
3	Amount of Category IV Cliff	2.67288	.177	.98630	.97279	.01818	.38585
4	Amount of Category I Cliff	4.11723	.135	.99425	.98853	.01574	.61048
5	Amount of Category II Cliff	6.86710	.120	.99871	.99741	.00888	.84559
Red-tailed Hawk Pairs							
1	Amount of Category II Cliff	51.82461	.000	.94670	.89624	.89624	.94670
2	March ground squirrel density	6.32311	.054	.97682	.95418	.05794	.93198
3	Amount of Category I Cliff	7.39116	.053	.99192	.98391	.02973	.61600
4	Amount of Category IV Cliff	.33544	.603	.99274	.98553	.00162	.41891
5	Total Cliff Area	1.35738	.364	.99568	.99138	.00585	.85300
Golden Eagle Pairs							
1	Total Cliff Area	16.83093	.006	.85860	.73720	.73720	.85860
2	March ground squirrel density	2.12834	.204	.90314	.81566	.07847	.41490
3	Amount of Category I Cliff	13.96637	.020	.97926	.95896	.14330	.16513
4	Amount of Category II Cliff	.84617	.425	.98386	.96799	.00903	.65654
Total Pairs							
1	March ground squirrel density	41.14015	.001	.93419	.87272	.87272	.93419
2	Total Cliff Area	8.55661	.033	.97625	.95306	.08034	.86432
3	Amount of Category II Cliff	.93978	.387	.98081	.96199	.00893	.85041
4	Amount of Category I Cliff	.86071	.422	.98512	.97046	.00847	.62870
5	Amount of Category IV Cliff	.90124	.443	.98977	.97964	.00918	.37253

Fig. 26. Distribution of the Townsend ground squirrel and the three major raptor species in the BPSA and Comparison Area.

Densities of nesting prairie falcons and red-tailed hawks are closely correlated with densities of Townsend ground squirrels in the BPSA and Comparison Area. Eagle densities, however, were relatively constant and unrelated to local variations in squirrel density.



DISTRIBUTION OF TOWNSEND GROUND SQUIRREL AND THE THREE MAJOR RAPTOR SPECIES IN THE BPSA AND COMPARISON AREA

compared to only 0.034 raptor pairs (0.004 prairie falcon pairs) per km^2 of cliff in the upstream Comparison Area, where shallow, coarse soils preclude the existence of ground squirrel populations. Prairie falcon densities were also low in the downstream Comparison Area, where ground squirrels are rare. Because of similar soils in this area (USDA 1972, USDA in prep.), the potential for ground squirrels is similar to that of the BPNA. Farming practices, however, have nearly eliminated ground squirrels from the north side of the downstream Comparison Area. Only 0.088 pairs nested per km^2 of cliff in the downstream Comparison Area, with only 0.018 prairie falcon pairs nesting per km^2 of cliff. Presumably, lack of squirrels is also the reason that high cliffs do not support high populations of prairie falcons in the intensively farmed areas near Twin Falls, 100 km upstream from the BPSA.

There is evidence, furthermore, that annual changes in prairie falcon density are related to annual changes in ground squirrel density. In 1975-76, when ground squirrel populations in the BPSA were high, 90.5% of traditional nesting sites were occupied by prairie falcons. In contrast, when squirrel populations were low in 1977-78, only 76.5% of the traditional sites were occupied. The canyon alone cannot ensure the continued existence of raptors along the Snake River. Reduction of prey, particularly ground squirrels, would result in the loss of raptors, primarily prairie falcons, from the area.

THE INFLUENCE OF PREY ON RAPTOR REPRODUCTIVE PERFORMANCE

Prairie falcons. Prairie falcons nesting in the BPSA during years of low ground squirrel abundance switched to other prey items. The reduced proportion of ground squirrels in their diet was accompanied by an increase in the consumption of birds, particularly rock doves, in 1977 and an increase in jackrabbits in 1978 (Fig. 24).

Although prairie falcons were able to shift to alternate prey in 1977 and 1978, the shift was energetically expensive. Ground squirrels contain roughly 50% more kilocalories per gram of tissue than alternate prey species in the BPSA (Table 22). Therefore, falcons obtained less energy for each gram of prey they carried back to the nest in 1977 and 1978. This loss of energy may have been critical when young were rapidly growing in the nest. In addition, rock doves are carriers of trichomoniasis (frounce), a disease that is often fatal to raptor nestlings (Stabler 1969). BLM researchers found no instances of frounce prior to the drought, but several cases were recorded in 1977.

The drop in both falcon nestling survival and percent of attempts successful in 1977-78 reflected the effects of these problems. Nestling survival averaged 89% during good ground squirrel years compared to 66% in 1977-78. Number of young fledged per pair in 1977-78 dropped sharply from the relatively constant level observed in the preceeding 5 years (Fig. 27).

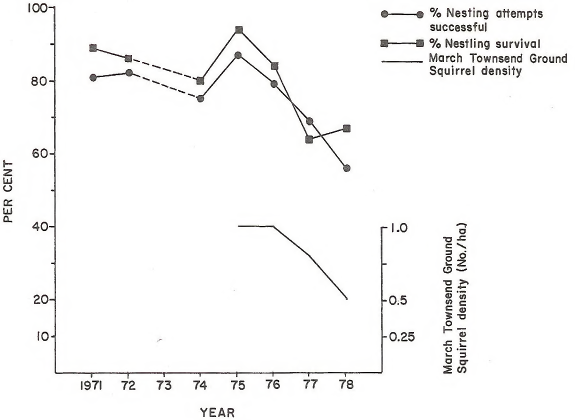
Linear regression analysis relating average March ground squirrel densities in the BPSA to prairie falcon productivity yielded a coefficient of determination (r^2) of .981, showing that ground squirrel

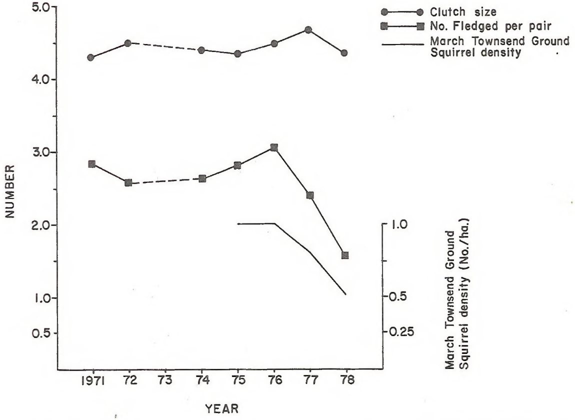
Table 22. Energetic contents (kcal/g wet weight) of prey taxa in the BPSA.

Taxon	kcal/g (wet weight)	Source
Black-tailed jackrabbit	1.329	Collopy 1978
Cottontail	1.329	- assumed same as jackrabbit
Townsend ground squirrel	2.201	Collopy 1978
Rodent	1.612	Fleharty et al. 1973
Upland game bird	1.693	Cummins and Wuycheck 1971
Passerine	1.810	Cummins and Wuycheck 1971
Lizard	1.320	Smith 1976

Fig. 27. Prairie falcon reproductive parameters and March Townsend ground squirrel densities for the BPSA, 1971-78.

The number of falcons fledged per pair dropped sharply in 1977 after a fairly constant 6-year level. The decline parallelled the drought-related decline of Townsend ground squirrels in the BPSA. Although clutch size did not change substantially over 8 years, nestling survival dropped sharply. The dashed lines indicate years for which data are not available.





PRAIRIE FALCON REPRODUCTIVE PARAMETERS AND MARCH TOWNSEND GROUND SQUIRREL DENSITIES FOR THE BPSA, 1971–78

densities accounted for more than 98% of the variation in annual numbers of prairie falcons fledged per pair (Fig. 28). There was no significant correlation between annual prairie falcon reproductive performance and jackrabbit densities ($r = .23$, $p > .05$). As mentioned earlier, the decline in ground squirrels in 1978 was associated with a drop in total number of falcon nesting pairs as well as the number fledged per pair. These close relationships indicate that ground squirrel abundance is limiting total prairie falcon reproduction in the BPSA.

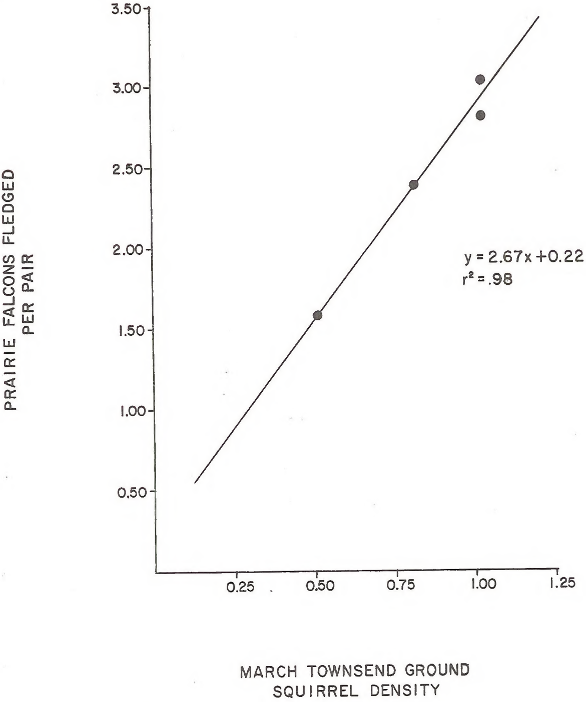
The specialized nature of prairie falcons is further reflected by the fact that prairie falcon breeding chronology closely corresponds to the ground squirrel's annual cycle. Prairie falcons arrive at nest sites in the BPSA in January just as ground squirrels emerge from 6 months of estivation (Fig. 29). Prairie falcon egg laying corresponds with the emergence of juvenile ground squirrels. Ground squirrel numbers are at a peak when young prairie falcons hatch, presumably the most energetically expensive period of the year for birds of prey. The gradual estivation of male, female, and juvenile ground squirrels from May to July corresponds to the fledging and dispersal of prairie falcons. By the time all squirrels are under ground, the prairie falcons have left the canyon until the following January.

Golden Eagles. Reproductive performance of eagles declined in response to declines of black-tailed jackrabbits, their major prey. Among eagle pairs occupying traditional sites, the proportion of eagles breeding declined from 100% in 1971, a good jackrabbit year, to an average of 65% in poor jackrabbit years (Fig. 30). Average clutch size showed no definite trend, but no 3-egg clutches were observed in poor jackrabbit years. Nestling survival declined markedly from good to poor jackrabbit years, and there were subsequent decreases in the percent of pairs that bred successfully, number of young fledged per successful attempt, and number of young eagles fledged per pair (Fig. 30). Yearly jackrabbit densities were correlated with both total number of eagles fledged ($r = .70$) and number fledged per pair ($r = .62$). Murphy (1975) suspected a similar relationship between golden eagle reproduction and jackrabbit abundance in Utah. There was no relationship between eagle reproduction and ground squirrel abundance in the BPSA ($r = -.5$).

Buteos. The number of red-tailed hawks fledged per pair was not related to yearly densities of either ground squirrels or jackrabbits ($r = .1$ and $-.2$ respectively). McInvaille and Keith (1974) also noted the lack of numerical response by red-tailed hawks to changes in prey densities in Alberta. Although red-tailed hawk productivity in the BPSA declined sharply in 1977 when ground squirrels crashed, it increased in 1978 when squirrel populations were lowest. The diverse diet of the red-tailed hawk apparently allows it to thrive even when one of its major prey becomes scarce. More specialized buteos may be more seriously affected, however. For example, Woffinden and Murphy (1977) observed declines in ferruginous hawk populations associated with jackrabbit declines.

Fig. 28. Linear regression relating number of prairie falcons fledged per pair to March ground squirrel densities in the BPSA, 1975-78.

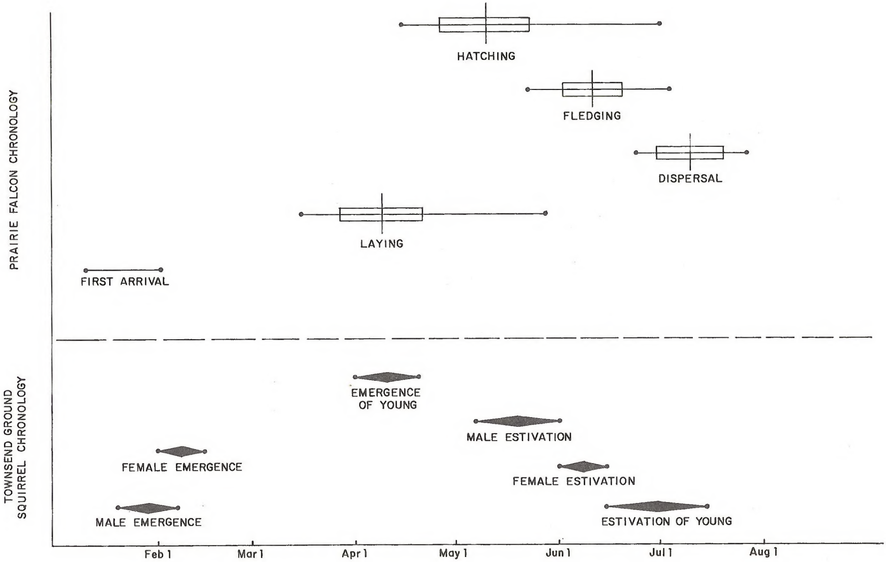
Results showed that March ground squirrel densities, averaged over the entire BPSA, were an excellent predictor of the number of prairie falcons fledged per pair.



LINEAR REGRESSION RELATING NUMBER OF PRAIRIE FALCONS FLEDGED PER PAIR TO MARCH GROUND SQUIRREL DENSITIES IN THE BPSA, 1975–78

Fig. 29. Prairie falcon and Townsend ground squirrel chronologies.

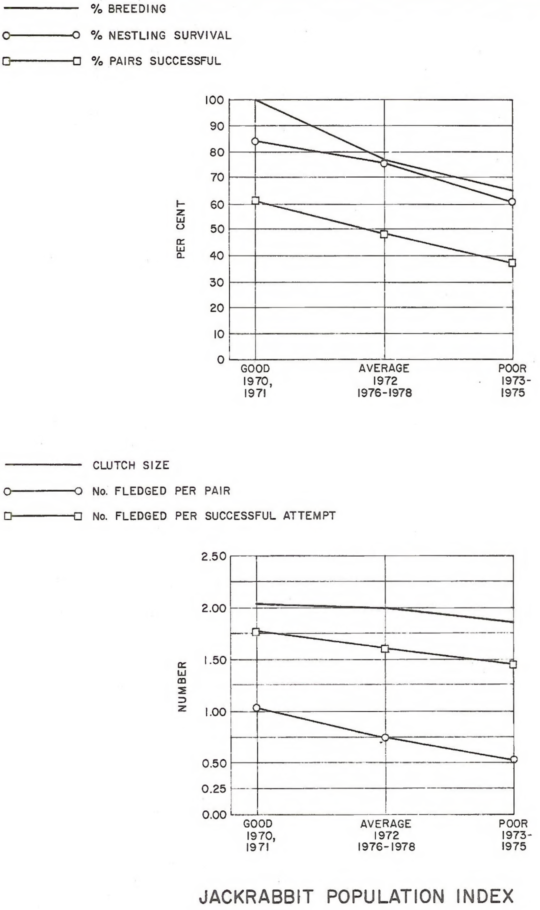
Prairie falcon breeding chronology corresponds closely to the above-ground chronology of Townsend ground squirrels. Falcons arrive at nest sites when the first ground squirrels emerge from estivation and disperse by the time all squirrels estivate again. The falcons' hatching and brood-rearing period corresponds to the time when the maximum number of squirrels are above ground.



PRAIRIE FALCON AND TOWNSEND GROUND SQUIRREL CHRONOLOGIES

Fig. 30. Golden eagle reproductive parameters as functions of the jackrabbit population index in the BPSA and Comparison Area, 1970-78.

The decline in jackrabbits was associated with a decline in the % of pairs successful. Average clutch size remained nearly the same regardless of jackrabbit abundance. The correlation between number of eagles fledged per pair and the jackrabbit index was significant at the .05 probability level.



GOLDEN EAGLE REPRODUCTIVE PARAMETERS AS FUNCTIONS OF THE JACKRABBIT POPULATION INDEX IN THE BPSA AND COMPARISON AREA, 1970–78

CONCLUSIONS and RECOMMENDATIONS

UNIQUENESS OF RAPTOR POPULATION

The unique combination of biotic and abiotic factors in the BPSA allows more raptors to occupy a given area of space than perhaps anywhere else in the world. The juxtaposition of abundant prey and cliffs, duplicated nowhere, is directly responsible for these high densities. The significance of the raptor populations in the BPSA is apparent when one contrasts their densities with those in other areas.

For comparative purposes, it is important to distinguish "crude densities" (Odum and Kuenzler 1955) that are based on total areas used by raptors from "nesting densities," which are based on an area encompassing only the nest sites. In areas with widely scattered pairs, the crude density would be similar to the nesting density. In areas like the BPSA, where nests are densely packed along a canyon, the crude density would be much lower than the nesting density. The BPSA is the only administrative area whose boundary was drawn specifically to encompass the home ranges of all its birds. The crude density for the BPSA would not be comparable to areas where political boundaries rather than raptor spatial use defined the study unit. The most meaningful comparison of areas is thus one based on nesting densities alone.

Raptor nesting densities observed in the BPSA were higher than in any other area reported in the literature. Of the 646 pairs in the BPSA (maximum observed nesting densities of each species in any year), 582 nest within a 532-km^2 belt encompassing the Snake River canyon. In this belt, there are 1.09 nests per km^2. In contrast, densities of intensively studied raptor populations in Utah, Washington, Colorado, and Michigan were 6 to 61% of that observed in this study (Table 23). Along the Colville River in the Alaskan wilderness, where cliff structure is similar to that in the BPSA, only 0.8 raptor pairs nested per linear km (White and Cade 1971), compared to 3.71 nests per linear km in the BPSA.

Raptor densities in other areas of Idaho were far below those observed in the BPSA. A survey of southern Idaho (Howard et al. 1976) showed raptor densities of only 0.37/km^2 outside of the BPSA, and a survey of the Snake River downstream from the BPSA and Comparison Area from Brownlee Reservoir to the confluence with the Columbia River showed densities of 0.41 sites per km of river (Asherin and Claar 1976).

BPSA nesting densities also compare favorably to densities outside North America. An area in the German Democratic Republic has 0.95 raptor pairs per km^2 (Wuhtky 1963), and the highly publicized region of Matapos, Rhodesia has only 0.58 pairs per km^2 (MacDonald and Gargett in prep.).

The density of raptors is only one of the factors that make the BPSA a unique and significant habitat for birds of prey. Species diversity is also remarkable for a North American situation. Although the

Table 23. Comparison of raptor nesting densities in the BPSA and other locations.

Location	Size (km^2)	Total No. Species	Total No. Pairs	Density ($pairs/km^2$)	Source
Eastern Washington	1036	10	44	0.04	Olendorff 1973a
Northeastern Colorado	2590	6	158	0.06	Olendorff 1975
Utah	207	12	40	0.19	Smith and Murphy 1973
Matopos, Rhodesia	620	33	357	0.58	MacDonald and Gargett in prep.
Michigan	96	9	64.5	0.67	Craighead and Craighead 1956
German Democratic Republic	130	5	124	0.95	Wuhtky 1963
BPSA	532*	15	582**	1.09	Current research

* Area of highest nesting density along the Snake River within the BPSA.

** Maximum observed yearly totals for each species combined.

number of raptor species nesting in Rhodesia exceeds that in the BPSA, more species nest in the BPSA than in any other North American area reported in the literature (Table 23). The diverse nesting population in the BPSA includes 5 species whose ranges are restricted to North America. Two of 15 nesting species (burrowing owls and ferruginous hawks) are classified as sensitive by the Bureau of Land Management and Idaho Fish and Game Department. In addition, two endangered raptorial species (the bald eagle and the peregrine falcon) use the BPSA during winter and while migrating.

SPATIAL REQUIREMENTS OF RAPTORS

Prairie falcons, red-tailed hawks, and golden eagles are probably now using the minimum amount of area they need to gather sufficient prey. Theoretical research (Emlen 1966, MacArthur and Pianka 1966, Schoener 1971) argues that home range size in a species is a result of natural selection and that, given certain assumptions (Wiens 1976), individuals tend to use range sizes optimal for reproduction and survival.

Prairie falcons in the BPSA used large home ranges, averaging 121 km^2 and extending as far as 25 km from the nest. Relative to other species, prairie falcons typically use large home ranges (Schoener 1968). Observed prairie falcon home ranges in California were as large as or larger than the ones observed in this study. Haak and Jarvis (1978) recorded ranges that averaged 180 km^2 and extended as far as 21 km from the nest while Harmata et al. (in prep.) recorded ranges averaging 104 km^2.

There are at least four main reasons why prairie falcons in general and in the BPSA specifically require large home ranges. First is the characteristic hunting style of the species. Prairie falcons have evolved as highly mobile predators and have been observed in this and other studies (Bond 1936, White 1962, Enderson 1964, Haak and Jarvis 1978, Harmata et al. in prep.) to hunt from a fast, low level flight. This "strafing" or "contour-hugging" technique takes advantage of the falcon's wing-loading characteristics (Brown and Amadon 1968) and capitalizes on surprising prey rather than outmaneuvering them. The technique requires large open spaces to be effective. Harmata et al. (in prep.) suggested that prairie falcons "may have to physically cover more total area...to get the equivalent hunting opportunities of the perched, optically superior eagle."

The tendency of prairie falcons to be specialized predators (Porter and White 1973) is the second reason that they must forage over large areas to secure food. Prairie falcons exhibit specific prey preferences and will concentrate on a single species as long as it is available (Bond 1936, Fyfe pers. comm.). The diet, density, breeding chronology, and reproductive success of prairie falcons in the BPSA were all highly dependent on ground squirrels. Ground squirrels were also recorded in 13 of 15 other studies of prairie falcon food habits, and they were listed as the main food source in at least 10 areas (Dawson 1913;

Fowler 1931; Bond 1936, 1942; Webster 1944; Enderson 1964; Platt 1971; Leedy 1972; Olendorff 1973b; Parker 1973; Porter and White 1973; Denton 1975; Oliphant et al. 1976; Haak and Jarvis 1978; Harmata et al. in prep.). Data from the BPSA showed a strong correlation between ground squirrel densities and falcon density and productivity. Because falcons depend on a single prey species, they are less likely to find enough prey in a single, small area and would therefore need to forage over a larger area.

Patchy distribution of prey in the hunting environment is the third main reason for large home range sizes of prairie falcons. Only scattered portions of the BPSA are usually suitable for efficient hunting. Only sage/bluegrass, winterfat, winterfat/sage, sage/winterfat, and dense grass cover types had squirrel densities greater than 10/ha in 1976. These scattered areas comprised less than 18% of the BPSA but produced more than 40% of all the ground squirrels in the BPSA. Of this area, only winterfat, winterfat/sage, and dense grass are the open cover types where squirrels would be expected to be vulnerable to falcon predation. Thus only 5% of the total BPSA has both high squirrel densities and cover suitable for falcon hunting, and these areas are interspersed with less suitable tracts. Similarly, Haak and Jarvis (1978) noted that prairie falcons in California hunted certain favorable patches of prey scattered throughout a large home range. It would be expected that if food sources were clumped in scattered areas, a larger overall foraging area would be needed (Orians 1971).

The fourth factor necessitating a large home range is intra- and interspecific competition. Ranges of prairie falcons overlap significantly throughout the BPSA. Given a mean distance of 0.6 km between pairs and a mean hunting territory width of 13.5 km, a pair could be sharing its foraging area with as many as 23 other pairs. In addition, prairie falcons share foraging areas near the canyon with golden eagle, red-tailed hawk and raven pairs. Thus, because individuals tend to avoid each other (Fuller 1979), portions of an individual's range will be temporarily unavailable while other individuals are hunting in those portions. In addition, the combined hunting pressure may either reduce prey densities or make prey more alert to avian predators in those areas (Wiens 1976). The non-territorial falcons are more likely to range farther out in response to these conditions than eagles and buteos that defend their foraging areas.

In contrast to prairie falcons, the eagles and buteos are specialized to hunt from perches and slow coursing or soaring flights (Brown and Amadon 1968). Their hunting efficiency does not depend on covering large open expanses. Because both eagles and red-tailed hawks have more diverse diets than prairie falcons, they are likely to encounter suitable prey in a wider variety of cover types and a smaller total area. Their ability to subsist in a smaller area allows buteos and eagles to economically defend a home range, and the subsequent reduction of competition further increases foraging opportunities.

Energetic constraints oblige birds to forage in the smallest area necessary to maximize individual genetic fitness, assuming that time and/or energy are limiting. Energy is at least sometimes limiting in the BPSA, as indicated by the decrease in prairie falcon reproduction when ground squirrel abundance declined, and the decrease in golden eagle reproduction when black-tailed jackrabbits declined. Under these conditions, natural selection will favor indivduals that exploit the resources in the environment most efficiently. Within a species, local conditions will dictate the amount of space required in any specific area. The home ranges in the BPSA recorded by radio telemetry, therefore, probably reflect the absolute requirements of the raptors given the current distribution of land use and cover types.

REPRODUCTIVE REQUIREMENTS FOR STABILITY

Prairie Falcons

The annual recruitment necessary for maintenance of a stable prairie falcon population can be calculated from a model developed by Henny et al. (1970) based on age-specific mortality rates and age at first breeding. According to Enderson (1969), 74% of prairie falcons die in their first year, and annual mortality rates are 25% for all ages thereafter. Age at first breeding is generally assumed to be 2 years for prairie falcons (Brown and Amadon 1968), but cases of breeding first year birds have been reported (Platt 1977). Since the proportion of breeding first-year falcons in the BPSA population is unknown, the calculations for recruitment necessary for population stability were performed according to the equations of Henny et al. (1970) for both Special Case I, breeding at end of the first year,

$$\overline{m} = \frac{1 - s}{s_o\ (1-s+s_1)},$$

and Special Case II, breeding at the end of the second year,

$$\overline{m} = \frac{1 - s}{s_o s_1\ (1-s+s_2)},$$

where $\overline{m}$ is the number of female offspring per breeding age female necessary for population stability; s_o, s_1, and s_2 are the survival rates for juvenile, first, and second-year falcons, respectively; and s is the survival rate after the age at first breeding. Because the sex ratio of prairie falcons at fledging is even (Ogden 1973, Denton 1975), falcons would need to produce 2 $\overline{m}$ offspring per pair per annum to maintain a stable population.

If all falcons breed in their first year, the population would need to produce 1.92 fledgings per pair to replace itself. If breeding occurs at the end of the second year, minimum necessary recruitment would be 2.56. Both of these critical levels are shown in Fig. 31. Because the age at first breeding in the BPSA is unknown, the safe, conservative approach would be to maintain productivity levels at or above 2.56 per pair per year (Special Case II).

Caution, however, must be exercised when interpreting the results of this model (Henny and Wight 1972). The output number of young per breeding female is meant to be a long-term average. It does not consider short-term fluctuations in environment, which undoubtedly occur, nor does it consider the need for "surplus" production as a buffer for bad years. In addition, Enderson's (1969) mortality schedule, based on band returns from prairie falcons banded before 1951, may not accurately reflect real mortality (Denton 1975). The Henny model calculations assume that all surviving young return to their natal area to breed. In fact, the BPSA may be a source of recruitment that regularly repopulates less productive regions. With these considerations in mind, overall productivity of birds in the BPSA based on several years of data can be compared to the Henny model results, and long-term population trends can be indicated.

Average falcon productivity observed during the pre-drought years of 1971-72 and 1974-76 (2.83 fledged per pair) indicated that falcons were more than replacing themselves (Fig. 25). Ogden and Hornocker (1977) considered the population reproductively healthy from 1971-72, and reproductive performance in 1974-76 was similar. During 1978, however, reproduction dropped well below the level sufficient to maintain the population. The 1978 reproduction was the result of a disadvantageous "environmental fluctuation," and presumably, the surplus produced in other years will balance the 1978 deficit over the long-term. Average productivity for the pre-drought and post-drought years combined was 2.59, just over the minimum necessary for long-term stability.

Golden Eagles

It is more difficult to assess the recruitment required for population stability for golden eagles than for prairie falcons because of the lack of data on eagle mortality rates. The status of the BPSA population can be appraised by comparing their long-term reproductive rate with that of other golden eagle populations reported in the literature.

The seven year average of 0.75 young fledged/pair/annum in the BPSA (Table 18) compares favorably with long-term averages in other areas. In Utah, 16 golden eagle pairs fledged an average of 0.69 young/pair/annum over 6 years (Murphy 1975). In Scotland, Watson (1957) observed 0.80 young fledged/pair/annum for 5 golden eagle pairs over 13 years. Brown (1974) reported a long-term average of 0.56 young fledged/pair/annum for golden eagles under the influence of human predation in Britain. He estimated this rate would be 0.83 without human interference. In Montana, Reynolds (1969) reported a 6 year average of 1.11 young fledged/breeding attempt. If the long-term average breeding rate (80%) for golden eagles (Brown and Amadon 1968) is applied to this population, these Montana eagles fledged an estimated 0.89 young/pair/annum. The combined average for all undisturbed golden eagle populations studied is 0.79 young fledged/pair/annum, only slightly above the BPSA average. Golden eagles in the BPSA, then, appear to be doing as well as those reported in the literature. This fact, in addition to the stable number of traditional eagle sites occupied in the BPSA, indicates a presently healthy, stable population of golden eagles in the BPSA.

Red-tailed Hawks

Henny and Wight (1972) calculated a long-term recruitment requirement for population stability of northern United States red-tailed hawks of 1.33-1.38 young fledged per breeding-age female. In the BPSA, red-tailed hawks from 1973-78 averaged 1.50 fledged per pair (Table 20). Given the cautions expressed earlier regarding the Henny model, this indicates a stable population, at least for the six years for which data exist.

EFFECTS OF AGRICULTURE

Effects on Prey

Additional agricultural development would reduce the total biomass of prey available to raptors in the BPSA. New agriculture supports less than 65% of the prey biomass and energy that is supported by native range (Table 24). Major prey species, Townsend ground squirrels and black-tailed jackrabbits, would suffer severe reductions. Several minor prey species not utilized extensively by the major raptors (passerines, pheasants, and rodents) would increase with agricultural development. Jackrabbits would not survive in agriculture, and squirrels would exist only temporarily in alfalfa fields. Poisoning, extensive use of farm machinery, and loss of cover and substrate would prevent jackrabbits and squirrels from maintaining populations in agricultural lands. Furthermore, because of both soil structure and fertility, the cover types most likely to be converted to agriculture (winterfat and sagebrush) are also the cover types where jackrabbits and ground squirrels are most abundant.

Although crop lands may provide a seasonally abundant food for jackrabbits and cottontails, they effectively eliminate the necessary cover for the animals. Various studies (Taylor and Lay 1944, Lechleitner 1957, Currie and Goodwin 1966, Westoby and Wagner 1973) have demonstrated that the quantity and quality of vegetative cover, rather than food *per se*, often constitute the limiting factors for lagmorphs. Westoby and Wagner (1973) found that 70% of the forage removal by jackrabbits in a crested wheatgrass field occurred within 300 m of its edge. Similarly, in this study jackrabbits were observed at night at the edges of alfalfa fields, adjacent to native range vegetation. However, considering the large size of the fields involved in recent agricultural development, the loss of cover from eliminating native vegetation for agriculture outweighs the largely ephemeral food source that the margins of most agricultural fields provide.

Effects on Raptors

Prairie falcons. The decrease in ground squirrels caused by agricultural development could result in a decrease in both density and reproductive performance of prairie falcons. Agricultural development in the downstream Comparison Area apparently has already reduced squirrel densities, and has resulted in a much lower number of falcons per unit of cliff than in adjacent unfarmed areas.

Table 24. Prey biomass and kilocalories per ha in new agriculture and native range in the BPSA.

	New Agriculture		Native Range*	
	g/ha	Kcal/ha	g/ha	Kcal/ha
Major Prey				
Jackrabbit	0.0	0.0	186.0	247.2
Townsend ground squirrel	30.0	66.0	327.5	720.7
Subtotal	30.0	66.0	513.4	967.8
Minor Prey				
Cottontail	15.3	20.4	42.9	57.0
Pheasant	34.1	57.8	0.0	0.0
Rodent	1,161.0	1,871.5	1,629.0	2,625.9
Lizard	0.0	0.0	138.8	183.2
Passerine	363.5	657.9	160.1	289.8
Subtotal	1,573.9	2,607.6	1,970.8	3,156.0
TOTAL	1,603.9	2,673.6	2,484.2	4,123.8

*based on current proportions of native cover types in the BPSA and on average prey densities.

To predict the effects of agricultural development on prairie falcons, conversion of the nine most farmable cover types north of the river (sagebrush, winterfat, and grass) was simulated on the computer. In the simulation, ground squirrel densities in the farmable types were replaced with ground squirrel densities for new agriculture (Tables 6 and 7). The conversions were simulated in 20% increments. For each 20% increment, average squirrel densities for the entire BPSA were recalculated. The number of falcons fledged per pair was then estimated using the least squares regression formula ($y = 2.67x + 0.22$) relating prairie falcon reproduction to average ground squirrel density throughout the BPSA (Fig. 28). Projected reductions in reproductive performance in both normal (1975-76) and poor (1978) ground squirrel years are shown in Fig. 31.

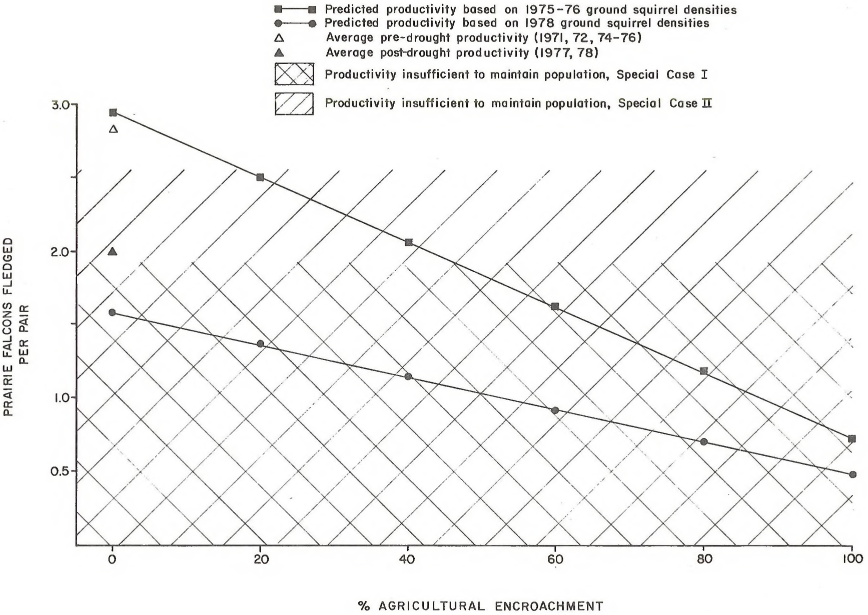
According to the computer simulations, as little as 15% agricultural conversion will reduce the number of falcons fledged per pair, even in the best of prey years, to a point where the population cannot replace itself. As shown earlier, these low levels of reproduction are tolerable for a short time as long as good reproduction in other years brings the long-term average above that needed to replace the population. Unlike the time-specific effects of drought, however, reduced reproduction associated with agriculture would be permanent. Even with a series of good prey years (Fig. 31), falcons would not be able to produce enough young to re-establish present population levels. Periodic droughts, however, must be anticipated in the region (Fig. 5). A drought similar to the one observed in 1977 would lower reproduction still further (Fig. 31), with a consequent reduction in the sustained population level.

The major long-term effect of agriculture may not be lower reproduction per pair so much as the loss of breeding pairs, i.e. reduced carrying capacity of the environment. According to the "decline syndrome," documented by peregrine falcon researchers (Hickey 1969, Prestt and Ratcliffe 1972), lower reproductive performance is only the first step in the decline of a raptor population. It is followed by the abandonment of traditional territories by pairs and an increase in the number of "one-bird" sites. Garrett and Mitchell (1973) observed such a decline among prairie falcons in the Central Valley of California, where only 1 of 33 traditional sites was occupied by prairie falcon pairs. They suggested that massive conversion of native range to agriculture was an important factor contributing to the population's demise. Galushin (1974) pointed out that migrating species of raptors will go on "searching migrations" if food resources are inadequate in their previous breeding area.

The BPSA falcons may already be experiencing an early stage of the "decline syndrome." Average reproduction from 1971-78 was just barely above that necessary to replace the population. However, preliminary 1979 data (Smith pers. comm.) show that ground squirrel populations are still 20-40% below pre-drought levels and have not yet recovered from the 1977 drought. It is possible that too much of the BPSA has already been farmed to allow prairie falcons to return to pre-drought population levels. Clearly, further agricultural development could lead to more severe and irreversible prairie falcon population declines.

Fig. 31. Predicted effects of agricultural encroachment and productivity levels necessary for prairie falcon population stability.

As little as 15% agricultural encroachment would lower falcon reproduction to levels insufficient to maintain the population. The cross-hatched areas show reproductive levels insufficient for maintenance of long-term population stability assuming all falcons bred in their first year. The diagonally-hatched area shows the same but assumes breeding is delayed until the second year, a more valid assumption. Thus long-term falcon productivity should be maintained above this level. Although post-drought productivity was below the critical replacement level, it was presumably balanced by higher reproduction in previous years, bringing the 8 year reproductive average just above the level necessary for replacement. Agricultural encroachment, unlike drought, will result in permanent prey reductions and permanently lower reproduction.



PREDICTED EFFECTS OF AGRICULTURAL ENCROACHMENT AND PRODUCTIVITY LEVELS NECESSARY FOR PRAIRIE FALCON POPULATION STABILITY

Golden eagles. Conversion of the nine farmable cover types would reduce the number of jackrabbits available to golden eagles. In an average jackrabbit year, a 40% increase in agriculture would reduce overall jackrabbit densities in the area hunted by eagles to a level similar to that observed during previous poor jackrabbit years. Increased farming in a poor year, of course, would lower jackrabbit densities even further. Wide fluctuations in jackrabbit population levels are common, and poor jackrabbit years should be expected approximately every 10 years (Gross et al. 1974).

The effects of agriculture on eagles cannot be predicted merely by simulating lower jackrabbit densities. Eagles are less specialized feeders than prairie falcons, and the correlation between eagle reproduction and their main prey species was not as strong as that for prairie falcons. In fact, pheasants, an important alternate prey for eagles, would increase with agricultural development, and the degree to which they may compensate for jackrabbits is unknown. The increase in pheasants and decrease in jackrabbits, however, would result in a net energy and biomass loss of 226 kcal/ha and 180 g/ha (Table 24).

Another method of predicting agricultural impacts on eagles is to examine the effects of existing crop land. At present, there are 13 traditional eagle territories in the BPSA in which more than 20% of the area within 2.65 km of the nest if farmed. Productivity and occupancy at these sites can be compared with territories with less than 20% of the home range farmed.

The proportion of vacant territories in agricultural areas was significantly higher than the proportion in non-agricultural areas (χ^2 = 10.81, df = 1, $P < .01$). Percent breeding was also lower in agricultural territories, but the difference was not significant (χ^2 = 0.67, df = 1, $.25 < P < .5$). Among eagles that bred, there were no apparent differences in productivity in the two types of areas.

These results cannot be considered conclusive, however, because much of the existing agriculture surrounding eagle nests is classified as old agriculture (Table 4). Further development would involve clean farming (new agriculture), with fewer pheasants and other birds in the agricultural areas and a more severe impact on the eagles. Additional agricultural development would probably cause abandonment of some traditional eagle territories and might also result in the failure of some pairs to breed.

Buteos. Because of its diverse diet, the red-tailed hawk would probably be the major raptor least affected by agricultural development. Although the 4 main red-tailed hawk prey taxa (ground squirrels, jackrabbits, cottontails, and reptiles) would decline with agriculture, secondary prey (birds, rodents) would increase. Red-tailed hawks have exhibited an ability to switch to other prey species (Luttich et al. 1970, McInvaille and Keith 1974). Populations in the eastern United States nest near agricultural areas (Craighead and Craighead 1956, Luttich et al. 1971, Gates 1972, Howell et al. 1978).

Although red-tailed hawks are adaptable and capable of using a wide variety of habitats (Luttich et al. 1970), there are indications that intensive cultivation adversely affects red-tailed hawk reproduction. Gates (1972) found that the 6-year productivity of a red-tailed hawk population in an intensively farmed area of Wisconsin was below the level required for the population to sustain itself. Howell et al. (1978) found that red-tailed hawk pairs near pastures had higher reproduction than those adjacent to cultivated fields. It would be reasonable to assume that large-scale, intensive, modern agriculture would have more of an impact on red-tailed hawks than the older agricultural situations cited above.

Ferruginous hawks may be less compatible with agriculture than red-tailed hawks. Although Wakeley (1978) recorded a male at one site foraging in cultivated fields during two seasons, ferruginous hawk populations do not apparently thrive in agricultural areas. Howard (1975) found that of 97 pairs studied in Utah, none nested in cultivated areas. Olendorff (1973b) reported that ferruginous hawks rarely nested near extensively cultivated areas in northeastern Colorado. Ferruginous hawks appear to be highly susceptible to disturbance and will readily abandon their nests (Powers et al. 1975, Fyfe and Olendorff 1976). Furthermore, they are sensitive to declines of their major prey (Woffinden and Murphy 1977). Development of large tracts of agriculture in the BPSA could reduce ferruginous hawk reproduction by increased disturbance, loss of habitat for prey, and the direct destruction of nests in the land clearing process.

Other effects. The discussion so far has been limited to the effects of agriculture as manifested through reduced prey densities. Assessment of the effects of pesticides and human disturbance associated with agriculture was beyond the scope of this study, but warrants brief discussion.

Use of organophosphate sprays, organochlorine soil fumigants, phenyl mercury fungicides and several phenoxy herbicides in the BPSA would increase with increased farm development. Organophosphates are highly toxic but are not persistent in the environment (Tucker and Crabtree 1970). They would probably not accumulate in the raptors but could directly affect some prey species. Present levels of organochlorine and mercury residues in BPSA hawks, falcons, and eagles are low compared to contaminated populations (Kochert 1972, BLM unpublished data) but would probably increase with increased local use. With the ban on the use of alkyl mercury seed dressings and many organochlorine insecticides in the BPSA in the early 1970's (Kochert 1972), the severe contamination problems observed elsewhere in the late 1960's (Hickey 1969, Peakall and Lovett 1972, Fyfe et al. 1976) are less likely to occur. Chemicals most likely to be used would be the organophosphate insecticides and phenoxy herbicides. Little is known about the long-term effects of phenoxy herbicides.

Increased agricultural development could disturb ground-nesting raptors such as Swainson's hawks, burrowing owls, ferruginous hawks and marsh hawks. All species nesting near developed areas would be subjected to disturbances such as road building, vehicular travel, and farm machinery

operations. In addition, the increased accessibility of the area would increase the chances for direct human disturbance, either malicious or simply from curiosity.

RECOMMENDED BOUNDARY

The objective of the proposed Snake River Birds of Prey National Conservation Area (BPNA) is to ensure the long-term stability of the raptor populations and the ecosystem that they inhabit. The eastern and western boundaries should delimit the dense raptor nesting population. As shown in Fig. 32, nesting densities drop sharply west of the western boundary of the BPSA and east of Hammett, logical locations for the boundary. Between these locations, the northern and southern boundary lines must be based on spatial requirements of the raptors, as determined by the research reported here.

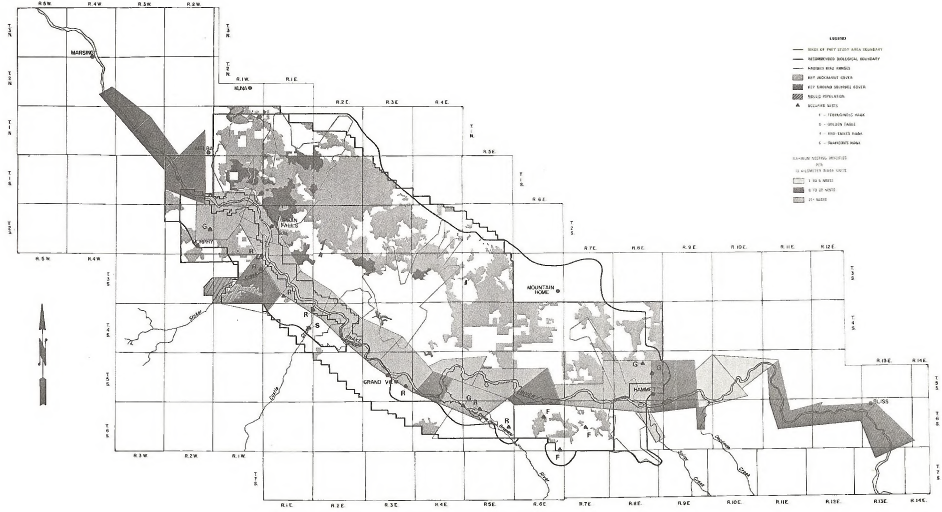
The boundary (Fig. 32) should follow the maximum dimensions of the individual ranges determined by radio telemetry. In sections where no birds were radio-tracked, the boundary should be drawn at the maximum distance flown from the nest by any radio-tracked pair to ensure that 100% of the foraging area of non-radioed raptors is included. Protection of a smaller area would have the same effects as agricultural conversion (Fig. 31) because many of the areas outside the Conservation Area are likely to be farmed. With reduced prey densities, reproduction of raptors, particularly prairie falcons, will decline, and there will be a subsequent loss of breeding pairs.

The northern boundary should be based on the ranges of prairie falcons, because radio-tracked falcons regularly hunted farther north of the canyon than any other species. Pairs flew a maximum of 25 km from the nest, with a mean home range width of approximately 13 km. All adjacent radio-tagged falcon pairs showed a large degree of range overlap (Figs. 17-19). Approximately 200 prairie falcon pairs nest along the Snake River in the BPSA, occurring on the average every 647 m (Table 15). This high nesting density combined with the large, overlapping ranges used by prairie falcons creates an essentially solid belt of falcon foraging area on the north side of the river that extends 25 km out from the canyon throughout most of the BPSA. This necessitates continuation of the boundary at this distance between ranges of radioed birds. East of the C.J. Strike Reservoir, the belt is compressed on the north side and extended on the south side to reflect the ranges of radioed prairie falcons in that area (Fig. 32).

The southern boundary should be drawn to include ranges of red-tailed hawks, ferruginous hawks, and golden eagles as data indicated very little foraging by falcons south of the river. The boundary should be based only on those pairs nesting within 1.6 km south of the southern rim of the canyon, because it is questionable whether pairs nesting farther from the canyon are truly part of the unique nesting density that is to be preserved. For the boundary shown in Fig. 32, mean maximum distances of 7 km for eagles and 6 km for red-tailed hawks were used as diameters of circles with the nest at the center, where it was known

Fig. 32. Biological basis for determining the proposed boundary of the Birds of Prey National Conservation Area.

The boundary was drawn to protect the dense population of breeding raptors along the Snake River Canyon. Because nesting densities drop sharply east of Hammett and west of the western BPSA boundary, these locations provided convenient points for drawing the eastern and western boundaries. The northern boundary was based on actual and estimated prairie falcon home ranges, and the southern boundary was based on home ranges of nesting golden eagles, red-tailed hawks and ferruginous hawks. The boundary was drawn to include the ranges of all radioed raptors, and in areas where no raptors were radio-tracked, the line followed the maximum distance flown from the canyon by the species in question. The southern boundary was extended to include the genetically unique population of the "Mollis" subspecies of Townsend ground squirrel.



BIOLOGICAL BASIS FOR DETERMINING THE PROPOSED BOUNDARY OF THE BPNCA

from observation that the pairs used both sides of the river. In cases where it was not known whether a pair used both sides of the river, or if it was impossible to use both sides, the mean maximum home range length was used as the radius with the nest at the center.

The southern boundary should be extended to include the isolated deme of *S. t. mollis* (Fig. 32). This single population of Townsend ground squirrels on the south side probably provides an important food source for prairie falcons and red-tailed hawks nesting nearby. Furthermore, as a separate subspecies, the population represents a genetic resource. Its apparent ability to withstand catastrophic drought may make it an important buffer species during future droughts or other adverse conditions.

The outer boundary in Fig. 32 delimits the minimum area required to insure long-term stability of the raptor populations. Barring unforeseen catastrophic climatic changes or plague outbreaks among the prey populations, effective management of the outlined area should ensure the continued existence of golden eagles, prairie falcons, red-tailed hawks and 12 other species of raptors nesting in the area.

It is important that the proposed area presented in Fig. 32 be considered a minimum area. The line was drawn to address the needs only of the large, abundant raptors breeding in the canyon. Although the proposed area will probably meet the needs of the smaller and less abundant birds of prey, it is uncertain whether the area is sufficient to sustain populations of floaters and wintering raptors not studied. According to Whitcomb et al. (1976), the sizes of ecological preserves should be maximized to ensure ecosystem stability. Retraction of the line at any point would fragment the system and compromise its integrity. Designating the line based upon the needs of the three major raptor species will allow management on an ecosystem basis. Rarely is a government agency able to establish a sanctuary boundary that is based on the needs of the inhabitants of the ecosystem. The present situation affords an opportunity unique in the history of natural resource conservation.

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APPENDIXES

Appendix A. July small rodent snap-trap results (number of captures/100 trap nights) in the BPSA, 1975-78.

Cover/Land Use	Deer Mouse	Pocket Mouse	Kangaroo Rat	Grasshopper Mouse	Canyon Mouse	Least Chipmunk
Big Sagebrush	11.9	1.1	0.5	1.1	0.0	0.6
Big Sagebrush-Winterfat	20.8	1.6	0.8	1.5	0.0	0.0
Winterfat	7.1	0.5	0.5	2.4	0.0	0.0
Grass (burn)	16.4	0.3	8.0	0.0	0.0	0.0
Grass	7.3	0.0	0.6	0.0	0.0	0.0
Big Sagebrush/Farm	10.3	0.0	11.6	1.3	0.0	0.0
Big Sagebrush-Winterfat/ Farm	8.5	0.0	9.3	0.0	0.0	0.0
Winterfat/Farm	7.0	0.0	12.7	0.0	0.0	0.0
Shadscale	11.7	0.0	0.0	1.4	0.0	0.0
Shadscale-Winterfat	11.0	1.2	3.7	1.0	0.0	0.0
Canyon Talus	40.9	3.5	0.0	0.0	2.7	0.0
Canyon Rim	8.6	0.0	0.0	0.0	0.0	0.0
Riparian	31.5	0.0	0.0	0.0	0.3	0.0
Greasewood	20.8	2.1	1.3	0.0	0.0	0.0

Appendix B. Weights used in calculating prey biomass.

Mammals	Size Class	Sex	Wt(g)	Reference
Shrew-Unid(*Sorex* spp.)	Average	Unknown	6	Burt & Grossenheider 1964
Bat-Unid	Average	Unknown	10	Porter & White 1973
Long-tailed Weasel	Juvenile	Unknown	85	Palmer 1954
(*Mustela frenata*)	Average	Unknown	178	Smith & Murphy 1973
Badger (*Taxidea taxus*)	Neonate	Unknown	2833	Messick pers. comm.
Coyote (*Canis latrans*)	Juvenile	Unknown	2043	Estimated
Domestic Cat (*Felis domesticus*)	Average	Unknown	1800	Estimated
Yellowbellied Marmot	Adult	Male	3900	Armitage et al. 1976
(*Marmota flaviventris*)	Adult	Unknown	3222	Armitage et al. 1976
	Juvenile	Unknown	500	Hall 1946
	Neonate	Unknown	500	Armitage et al. 1976
	Intermediate	Male	2530	Armitage et al. 1976
	Intermediate	Unknown	2797	Armitage et al. 1976
	Average	Unknown	2797	Armitage et al. 1976
Townsend Ground Squirrel	Juvenile-April	Male	81	Smith pers. comm.
(*Spermophilus townsendi*)	Juvenile-April	Female	81	Smith pers. comm.
	Juvenile-April	Unknown	81	Smith pers. comm.
	Adult & Yearling: April	Male	218	Smith pers. comm.
	Adult & Yearling: April	Female	175	Smith pers. comm.
	Adult & Yearling: April	Unknown	195	Smith pers. comm.
	Juvenile:May	Male	142	Smith pers. comm.
	Juvenile:May	Female	131	Smith pers. comm.
	Juvenile:May	Unknown	137	Smith pers. comm.
	Adult & Yearling; May-June	Male	249	Smith pers. comm.
	Adult & Yearling: May-June	Female	189	Smith pers. comm.
	Adult & Yearling: May-June	Unknown	216	Smith pers. comm.
	Juvenile:June-July	Female	189	Smith pers. comm.
	Juvenile:June-July	Unknown	179	Smith pers. comm.
	Size unk-April	Unknown	138	Smith pers. comm.
	Size unk-May-July	Unknown	181	Smith pers. comm.

Appendix B (cont.). Weights used in calculating prey biomass.

Mammals (cont.)	Size Class	Sex	Wt(g)	Reference
White-tailed Antelope Squirrel (*Ammospermophilus leucurus*)	Adult	Male	111	Hall 1946
	Adult	Unknown	106	Hall 1946
	Juvenile	Unknown	40	Fisher 1976
	Average	Unknown	106	Hall 1946
Ground Squirrel-Unid	Adult	Unknown	172	Smith pers. comm.
	Average	Unknown	172	Smith pers. comm.
Least Chipmunk (*Eutamias minimus*)	Average	Unknown	32	Schreiber 1973
Pocket Gopher-Unid (*Thomomys* spp.)	Adult	Male	200	Estimated
	Adult	Female	200	Estimated
	Adult	Unknown	200	Estimated
	Juvenile	Male	100	Estimated
	Juvenile	Female	100	Estimated
	Juvenile	Unknown	100	Estimated
	Average	Unknown	200	Estimated
Great Basin Pocket Mouse (*Perognathus parvus*)	Juvenile	Unknown	10	Estimated
	Average	Unknown	15	Smith & Murphy 1973
Ord Kangaroo Rat (*Dipodomys ordi*)	Adult	Male	53	Schreiber 1973
	Average	Unknown	53	Schreiber 1973
Kangaroo Rat-Unid (*Dipodomys* spp.)	Adult	Male	53	Schreiber 1973
	Adult	Female	53	Schreiber 1973
	Adult	Unknown	53	Schreiber 1973
	Juvenile	Female	28	Bradley & Mauer 1971
	Juvenile	Unknown	53	Schreiber 1973
	Average	Unknown	53	Schreiber 1973
Harvest Mouse (*Reithrodontomys megalotis*)	Adult	Male	11	Schreiber 1973
	Adult	Unknown	11	Schreiber 1973
	Juvenile	Unknown	11	Schreiber 1973
	Average	Unknown	11	Schreiber 1973
Deer Mouse (*Peromyscus maniculatus*)	Adult	Unknown	19	Schreiber 1973
	Juvenile	Male	19	Schreiber 1973
	Juvenile	Unknown	10	Estimated
	Average	Unknown	19	Schreiber 1973
Grasshopper Mouse (*Onychomys leucogaster*)	Adult	Unknown	33	Burt & Grossenheider 1964
Mouse-Unid	Juvenile	Unknown	13	Estimated
	Intermediate	Unknown	25	Estimated
	Average	Unknown	25	Estimated

Appendix B (cont.). Weights used in calculating prey biomass.

Mammals (cont.)	Size Class	Sex	Wt(g)	Reference
Desert Woodrat	Adult	Unknown	150	Montan pers. comm.
(*Neotoma lepida*)	Average	Unknown	150	Montan pers. comm.
Bushy-Tailed Woodrat	Adult	Unknown	310	Montan pers. comm.
(*Neotoma cinerea*)	Juvenile	Unknown	155	Martin 1973
	Average	Unknown	310	Montan pers. comm.
Woodrat-Unid	Adult	Unknown	230	Montan pers. comm.
(*Neotoma* spp.)	Juvenile	Unknown	150	Oftedahl pers. comm.
	Average	Unknown	230	Montan pers. comm.
Muskrat	Adult	Unknown	1277	Donahoe 1966
(*Ondatra zibethica*)	Juvenile	Unknown	1065	Donahoe 1966
	Average	Unknown	1171	Donahoe 1966
House Mouse (*Mus musculus*)	Average	Unknown	17	Schreiber 1973
Meadow Mouse (*Microtus* spp.)	Adult	Female	30	Montan pers. comm.
	Adult	Unknown	30	Montan pers. comm.
	Juvenile	Unknown	28	Burt & Grossenheider 1964
	Average	Unknown	30	Montan pers. comm.
Rodent-Unid	Adult	Unknown	50	Estimated
	Average	Unknown	50	Estimated
Porcupine (*Erethizon dorsatum*)	Adult	Unknown	5800	Smith pers. comm.
Blacktailed Jackrabbit	Adult	Male	1878	Stoddart pers. comm.
(*Lepus californicus*)	Adult	Female	2342	Stoddart pers. comm.
	Adult	Unknown	2110	Stoddart pers. comm.
	Juvenile	Male	471	Stoddart pers. comm.
	Juvenile	Female	471	Stoddart pers. comm.
	Juvenile	Unknown	471	Stoddart pers. comm.
	Neonate	Unknown	100	Stoddart pers. comm.
	Intermediate	Male	1557	Stoddart pers. comm.
	Intermediate	Unknown	1557	Stoddart pers. comm.
	Average	Unknown	1379	Stoddart pers. comm.
	Fetus	Unknown	20	Estimated
Mountain Cottontail	Adult	Male	590	Montan pers. comm.
(*Sylvilagus nuttalli*)	Adult	Female	720	Montan pers. comm.
	Adult	Unknown	650	Montan pers. comm.
	Juvenile	Male	215	Montan pers. comm.
	Juvenile	Female	215	Montan pers. comm.
	Juvenile	Unknown	215	Montan pers. comm.

Appendix B (cont.). Weights used in calculating prey biomass.

Mammals (cont.)	Size Class	Sex	Wt(g)	Reference
Mountain Cottontail	Neonate	Female	100	Montan pers. comm.
(*Sylvilagus nuttalli*)	Neonate	Unknown	100	Montan pers. comm.
(cont.)	Intermediate	Female	500	Montan pers. comm.
	Intermediate	Unknown	500	Montan pers. comm.
	Average	Female	514	Montan pers. comm.
	Average	Unknown	514	Montan pers. comm.
Pygmy Rabbit	Adult	Unknown	340	Burt & Grossenheider 1964
(*Sylvilagus idahoensis*)	Average	Unknown	340	Burt & Grossenheider 1964
Rabbit-Unid	Adult	Unknown	650	Estimated
	Juvenile	Unknown	343	Estimated
	Neonate	Unknown	100	Estimated
	Intermediate	Unknown	1029	Estimated
	Average	Unknown	947	Estimated
Mule Deer (*Odocoileus hemionus*)	Juvenile	Unknown	6300	McGahan 1966
Pronghorn (*Antilocapra americana*)	Neonate	Unknown	2700	Beuchner 1950
Birds				
Great Blue Heron (*Ardea herodias*)	Average	Unknown	1905	Poole 1938
Canada Goose (*Branta canadensis*)	Juvenile	Unknown	450	Estimated
Mallard (*Anas platyrhynchos*)	Adult	Male	1248	Bellrose 1976
	Adult	Female	1107	Bellrose 1976
	Adult	Unknown	1185	Bellrose 1976
	Average	Unknown	1185	Bellrose 1976
Pintail (*Anas acuta*)	Adult	Male	1025	Bellrose 1976
	Adult	Unknown	976	Bellrose 1976
Green-Winged Teal	Adult	Male	322	Bellrose 1976
(*Anas carolinensis*)	Adult	Female	309	Bellrose 1976
Blue-Winged Teal (*Anas discors*)	Adult	Unknown	323	Owen 1970
Cinnamon Teal	Adult	Female	354	Bellrose 1976
(*Anas cyanoptera*)	Average	Unknown	1505	Craighead & Craighead 1956

Appendix B (cont.). Weights used in calculating prey biomass.

Birds (cont.)	Size Class	Sex	Wt(g)	Reference
Teal-Unid	Average	Unknown	354	Bellrose 1976
American Wigeon (*Anas americana*)	Adult	Female	767	Bellrose 1976
	Intermediate	Unknown	772	Bellrose 1976
Shoveler (*Anas clypeata*)	Adult	Male	681	Bellrose 1976
Duck-Unid	Adult	Male	850	Estimated
	Adult	Unknown	260	Estimated
	Juvenile	Unknown	425	Estimated
	Baby	Unknown	100	Estimated
	Average	Unknown	180	Estimated
Red-Tailed Hawk (*Buteo jamaicensis*)	Adult	Female	1056	BLM Data
	Juvenile	Unknown	800	Collopy pers. comm.
	Average	Unknown	1056	BLM Data
Ferruginous Hawk (*Buteo regalis*)	Intermediate	Unknown	1056	Estimated
Prairie Falcon (*Falco mexicanus*)	Intermediate	Male	675	BLM Data
	Intermediate	Unknown	675	BLM Data
Kestrel (*Falco sparverius*)	Adult	Unknown	114	Craighead & Craighead 1956
	Juvenile	Unknown	57	Estimated
	Average	Unknown	114	Craighead & Craighead 1956
Bobwhite (*Colinus virginianus*)	Adult	Male	137	Johnsguard 1973
California Quail (*Lophortyx californicus*)	Adult	Male	170	Lewin 1963
	Adult	Unknown	170	Lewin 1963
	Juvenile	Unknown	70	Lewin 1963
	Average	Unknown	170	Lewin 1963
Ring-Necked Pheasant (*Phasianus colchicus*)	Adult	Male	1371	Fimreite 1971
	Adult	Female	905	Anderson 1969
	Adult	Unknown	1138	Fimreite 1971, Anderson 1969
	Juvenile	Unknown	600	Estimated
	Intermediate	Female	905	Anderson 1969
	Average	Female	905	Anderson 1969
	Average	Unknown	1138	Fimreite 1971, Anderson 1969
Chukar (*Alectoris graeca*)	Adult	Unknown	602	Galbreath & Moreland 1953
	Juvenile	Unknown	300	Estimated
	Average	Unknown	602	Galbreath & Moreland 1953

Appendix B (cont.). Weights used in calculating prey biomass.

Birds (cont.)	Size Class	Sex	Wt(g)	Reference
Gray Partridge (*Perdix perdix*)	Adult	Unknown	389	Nelson and Martin 1953
	Average	Unknown	389	Nelson and Martin 1953
Domestic Chicken	Adult	Unknown	3120	Welty 1962
	Average	Unknown	3120	Welty 1962
	Bantam	Unknown	908	Estimated
Galliformes-Unk	Adult	Unknown	575	Estimated
	Juvenile	Unknown	400	Estimated
	Average	Unknown	485	Estimated
Rail-Unid	Adult	Unknown	70	Poole 1938
Coot (*Fulica americana*)	Adult	Unknown	654	Fredrickson 1969
	Average	Unknown	654	Fredrickson 1969
Killdeer (*Charadrius vociferus*)	Adult	Unknown	104	Robbins pers. comm.
Charadriiformes-Unid	Adult	Female	497	Estimated
	Adult	Unknown	497	Estimated
Ring-billed Gull (*Larus delawarensis*)	Juvenile	Unknown	497	Vermeer 1970
Gull-Unid (*Larus* spp.)	Adult	Unknown	633	Vermeer 1970
	Average	Unknown	633	Vermeer 1970
Rock Dove (*Columba livia*)	Adult	Unknown	332	Berglund pers. comm.
	Juvenile	Unknown	332	Berglund pers. comm.
	Intermediate	Unknown	332	Berglund pers. comm.
	Average	Unknown	332	Berglund pers. comm.
Mourning Dove (*Zenaida macroura*)	Juvenile	Unknown	131	Ivacic & Labisky 1973
	Average	Unknown	134	Ivacic & Labisky 1973
Barn Owl (*Tyto alba*)	Adult	Unknown	603	Marti 1973
Great Horned Owl (*Bubo virginianus*)	Adult	Unknown	1505	Craighead & Craighead 1956
	Intermediate	Unknown	1505	Craighead & Craighead 1956
Burrowing Owl (*Speotyto cunicularia*)	Juvenile	Unknown	170	Thomsen 1971
	Average	Unknown	170	Thomsen 1971
Short-Eared Owl (*Asio flammeus*)	Adult	Unknown	348	Clark 1975
	Juvenile	Unknown	348	Clark 1975

Appendix B (cont.). Weights used in calculating prey biomass.

Birds (cont.)	Size Class	Sex	Wt (g)	Reference
Poor-will (*Phalaenoptilus nuttallii*)	Adult	Unknown	43	Lasiewski et al. 1966
Nighthawk (*Chordeiles minor*)	Adult	Unknown	106	Esten 1931
	Juvenile	Unknown	106	Esten 1931
Says Phoebe (*Sayornis saya*)	Adult	Unknown	28	Behle 1944
	Average	Unknown	28	Behle 1944
Horned Lark (*Eremophila alpestris*)	Adult	Unknown	26	Trost 1972
	Juvenile	Unknown	17	Beason & Franks 1973
	Average	Unknown	26	Trost 1972
Cliff Swallow (*Petrochelidon pyrrhonota*)	Adult	Unknown	25	Withers 1977
Swallow-Unid	Adult	Unknown	25	Withers 1977
	Average	Unknown	25	Withers 1977
Blue Jay (*Cyanocitta cristata*)	Adult	Unknown	74	Esten 1931
Blackbilled Magpie (*Pica pica*)	Adult	Unknown	170	Linsdale 1937
	Juvenile	Unknown	170	Linsdale 1937
	Intermediate	Unknown	170	Linsdale 1937
	Average	Unknown	170	Linsdale 1937
Raven (*Corvus corax*)	Juvenile	Unknown	650	BLM Data
	Intermediate	Unknown	887	BLM Data
	Average	Unknown	887	BLM Data
Red-Breasted Nuthatch (*Sitta canadensis*)	Adult	Unknown	11	Mugas & Templeton 1970
Long-Billed Marsh Wren (*Telmatodytes palustris*)	Average	Unknown	11	Robbins pers. comm.
Canyon Wren (*Catherpes mexicanus*)	Adult	Unknown	10	Johnson 1965
Rock Wren (*Salpinctes obsoletus*)	Adult	Unknown	17	Easterla 1973
	Juvenile	Unknown	17	Easterla 1973
	Average	Unknown	17	Easterla 1973
Sage Thrasher (*Oreoscoptes montanus*)	Adult	Unknown	37	Killpak 1970

Appendix B (cont.). Weights used in calculating prey biomass.

Birds (cont.)	Size Class	Sex	Wt(g)	Reference
Robin	Adult	Unknown	79	Robbins pers. comm.
(*Turdus migratorius*)	Average	Unknown	79	Robbins pers. comm.
Mountain Bluebird (*Sialia currucoides*)	Adult	Unknown	20	Power 1966
Water Pipit (*Anthus spinoletta*)	Adult	Unknown	19	Poole 1938
Loggerhead Shrike (*Lanius ludovicianus*)	Average	Unknown	51	Robbins pers. comm.
Starling	Adult	Unknown	79	Robbins pers. comm.
(*Sturnus vulgaris*)	Average	Unknown	79	Robbins pers. comm.
Yellow Warbler (*Dendroica petechia*)	Average	Unknown	10	Robbins pers. comm.
Yellow-Breasted Chat	Adult	Unknown	26	Stewart 1937
(*Icteria virens*)	Average	Unknown	23	Stewart 1937
Western Meadowlark	Adult	Unknown	96	Balph 1973
(*Sturnella neglecta*)	Adult	Unknown	96	Balph 1973
	Juvenile	Unknown	40	Estimated
	Average	Unknown	96	Balph 1973
Yellow-Headed Blackbird	Adult	Male	91	Willson 1966
(*Xanthocephalus*	Adult	Female	56	Willson 1966
xanthocephalus)	Adult	Unknown	74	Willson 1966
Red-Winged Blackbird (*Agelaius phoeniceus*)	Average	Unknown	48	Robbins pers. comm.
Northern Oriole (*Icterus galbula*)	Adult	Male	33	Baldwin & Kendeigh 1938
Brewers Blackbird (*Euphagus cyanocephalus*)	Average	Unknown	68	Porter & White 1973
Brown-Headed Cowbird (*Molothrus ater*)	Adult	Unknown	41	Robbins pers. comm.
Lazuli Bunting (*Passerina amoena*)	Adult	Unknown	15	Bock and Lynch 1970

Appendix B (cont.). Weights used in calculating prey biomass.

Birds (cont.)	Size Class	Sex	Wt(g)	Reference
House Finch	Adult	Male	22	Robbins pers. comm.
(*Carpodacus mexicanus*)	Adult	Unknown	22	Robbins pers. comm.
	Average	Unknown	22	Robbins pers. comm.
Rufous-Sided Towhee	Adult	Unknown	41	Robbins pers. comm.
(*Pipilo erythrophthalmus*)	Average	Unknown	41	Robbins pers. comm.
Grasshopper Sparrow (*Ammodramus savannarum*	Adult	Unknown	17	Wiens pers. comm.
Lark Sparrow (*Chondestes grammacus*)	Average	Unknown	28	Robbins pers. comm.
Sage Sparrow	Adult	Unknown	24	Balph 1973
(*Amphispiza belli*)	Juvenile	Unknown	10	Estimated
	Average	Unknown	24	Balph 1973
White-Crowned Sparrow (*Zonotrichia leucophrys*)	Average	Unknown	27	Morton et al. 1973
Song Sparrow (*Melospiza melodia*)	Adult	Unknown	21	Baldwin & Kendeigh 1938
Sparrow-Unid	Adult	Unknown	26	Estimated
	Juvenile	Unknown	10	Estimated
	Average	Unknown	26	Estimated
Passerine-Unid	Adult	Unknown	56	Estimated
	Juvenile	Unknown	28	Estimated
	Intermediate	Unknown	56	Estimated
	Average	Unknown	56	Estimated
Bird Eggs	Average	Unknown	20	Estimated
Amphibians				
Spadefoot Toad (*Scaphiopus intermontnaus*)	Average	Unknown	12	Seymour 1973
Woodhouse Toad (*Bufo woodhousei*)	Average	Unknown	20	Diller pers. comm.
Toad-Unid	Average	Unknown	20	Estimated

Appendix B (cont.). Weights used in calculating prey biomass.

Amphibians (cont.)	Size Class	Sex	Wt (g)	Reference
Leopard Frog (*Rana pipiens*)	Average	Unknown	38	Seymour 1973
Bullfrog	Juvenile	Unknown	250	Estimated
(*Rana catesbeiana*)	Average	Unknown	500	Estimated
Frog-Unid	Average	Unknown	30	Estimated
Reptiles				
Collared Lizard (*Crotaphytus collaris*)	Average	Unknown	28	Diller pers. comm.
Leopard Lizard	Adult	Unknown	26	Diller pers. comm.
(*Crotaphytus wislizenii*)	Average	Unknown	23	Diller pers. comm.
Western Fence Lizard	Adult	Unknown	17	Diller pers. comm.
(*Sceloporus occidentalis*)	Average	Unknown	17	Diller pers. comm.
Side-Blotched Lizard (*Uta stansburiana*)	Average	Unknown	4	Diller pers. comm.
Horned Lizard	Adult	Unknown	24	Diller pers. comm.
(*Phrynosoma platyrhinos*)	Average	Unknown	18	Diller pers. comm.
Whiptail Lizard	Adult	Unknown	17	Diller pers. comm.
(*Cnemidophorus tigris*)	Intermediate	Unknown	15	Diller pers. comm.
	Average	Unknown	15	Diller pers. comm.
Lizard-Unid	Juvenile	Unknown	8	Estimated
	Average	Unknown	16	Estimated
Racer	Adult	Unknown	77	Diller pers. comm.
(*Coluber constrictor*)	Intermediate	Unknown	77	Diller pers. comm.
	Average	Unknown	77	Diller pers. comm.
Striped Whipsnake	Intermediate	Unknown	109	Diller pers. comm.
(*Masticophis taeniatus*)	Average	Unknown	109	Diller pers. comm.
Gopher Snake	Adult	Female	305	Diller pers. comm.
(*Pituophis melanoleucus*)	Adult	Unknown	250	Diller pers. comm.
	Juvenile	Unknown	19	Diller pers. comm.
	Baby	Unknown	19	Diller pers. comm.
	Intermediate	Unknown	211	Diller pers. comm.
	Average	Unknown	211	Diller pers. comm.

Appendix B (cont.). Weights used in calculating prey biomass.

Reptiles (cont.)	Size Class	Sex	Wt(g)	Reference
Long-Nosed Snake (*Rhinocheilus lecontei*)	Adult	Unknown	54	Diller pers. comm.
Garter Snake (*Thamnophis elegans*)	Average	Unknown	109	Diller pers. comm.
Ground Snake (*Sonora semiannulata*)	Juvenile	Unknown	2	Diller pers. comm.
	Intermediate	Unknown	8	Diller pers. comm.
	Average	Unknown	8	Diller pers. comm.
Nightsnake (*Hypsiglena torquata*)	Juvenile	Unknown	14	Diller pers. comm.
	Average	Unknown	14	Diller pers. comm.
Western Rattlesnake (*Crotalus viridis*)	Juvenile	Unknown	19	Diller pers. comm.
	Baby	Unknown	19	Diller pers. comm.
	Intermediate	Unknown	159	Diller pers. comm.
	Average	Unknown	400	Diller pers. comm.
Snake-Unid	Adult	Unknown	207	Estimated
	Juvenile	Unknown	19	Estimated
	Intermediate	Unknown	207	Estimated
	Average	Unknown	207	Estimated
Reptile-Unid	Juvenile	Unknown	138	Estimated
	Average	Unknown	138	Estimated
Fishes				
Whitefish (*Prosopium williamsoni*)	Average	Unknown	80	Estimated
Carp (*Cyprinus carpio*)	Adult	Unknown	583	Steenhof 1976
	Average	Unknown	583	Steenhof 1976
Chisel Mouth (*Acrocheilus alutaceus*)	Adult	Unknown	80	Estimated
Northern Squawfish (*Ptychocheilus oregonesis*)	Adult	Unknown	100	Estimated
	Intermediate	Unknown	80	Estimated
	Average	Unknown	90	Estimated
Sucker (*Catostomus* spp.)	Adult	Unknown	120	Estimated
	Intermediate	Unknown	100	Estimated
	Average	Unknown	110	Estimated

Appendix B (cont.). Weights used in calculating prey biomass.

Fishes (cont.)	Size Class	Sex	Wt(g)	Reference
Sunfish	Juvenile	Unknown	60	Estimated
(*Lepomis* spp.)	Average	Unknown	80	Estimated
Small Mouth Bass	Adult	Unknown	700	Niimi and Beamish 1974
(*Micropterus dolomieui*)	Juvenile	Unknown	200	Niimi and Beamish 1974
	Average	Unknown	500	Niimi and Beamish 1974
Centrarchid Fish	Juvenile	Unknown	60	Estimated
	Average	Unknown	80	Estimated
Yellow Perch	Average	Unknown	80	Reynolds & Karlotski 1977
(*Perca flavavescens*)	Average	Unknown	1	Estimated
Fish-Unid	Juvenile	Unknown	60	Estimated
	Average	Unknown	583	Estimated
Arthropods				
Crayfish (*Decapoda* spp.)	Adult	Unknown	3	Estimated
Scorpion	Adult	Unknown	1	Smith & Murphy 1973
(*Scorpionidae*)	Juvenile	Unknown	1	Smith & Murphy 1973
	Intermediate	Unknown	1	Smith & Murphy 1973
	Average	Unknown	1	Smith & Murphy 1973
Spider	Average	Unknown	1	Estimated
Cicada (*Circadidae*)	Adult	Unknown	1	Estimated
Grasshopper (*Locustidae*)	Average	Unknown	1	Smith & Murphy 1973
Jerusalum Cricket (*Gryllacridae*)	Average	Unknown	2	Evans & Emlen 1947
Beetle (*Scarabidae*)	Average	Unknown	1	Estimated
Wasp, Bee (*Hymenoptera*)	Average	Unknown	1	Estimated
Insects-Unid	Average	Unknown	1	Estimated
Misc.				
Corn	Average	Unknown	1	Estimated

Appendix C. Dimensions of golden eagle home ranges in the BPSA during the brood-rearing and post-fledging periods, 1976-77.

Individual/site	Home range (km^2)	Maximum dist. from nest (km)	Maximum length of home range (km)	Maximum width of home range along the canyon (km^2)
		INDIVIDUALS		
		(1977)		
Cabin Draw ♀	18	5	7	5
Cove ♀	5	4	5	5
Cove ♂	5	4	5	5
Beecham ♀ *	43	15	17	7
Black Butte ♂	14	6	8	3
Black Butte ♀	12	6	7	3
MEAN	16	7	8	5
		PAIRS		
		(1976)		
Feedlot	49	8	10	7
Cabin Draw	20	5	7	4
MEAN	35	7	9	6
		(1977)		
Cabin Draw**	20	5	7	5
Cove	5	4	5	5
Black Butte	14	6	8	3
MEAN	13	5	7	4
MEAN, BOTH YEARS	22	6	7	5

* Radioed after nest failure

** Non breeding pair

Appendix D. Dimensions of prairie falcon home ranges in the BPSA during the brood-rearing and post-fledging periods, 1975-77.

Individual/ Site	Home range (km^2)	Max. dist. from nest (km)	Max. dist. from river (km)	Max. width of home range along the canyon (km)
		INDIVIDUALS		
		1975		
PF-1 ♀	58	14	15	11
PF-2 ♀	142	21	22	14
PF-2 ♂	66	18	19	9
MEAN	89	18	19	11
		1976		
PF-New ♂	35	15	15	4
PF-2 ♀	85	22	22	13
Camera ♂	56	15	16	12
Camera ♀	116	26	26	14
Loaf ♂	110	25	29	14
Loaf ♀	102	26	30	12
Hump ♂	44	14	18	7
Hump ♀	80	22	26	8
MEAN	79	21	23	11
		1977		
Trail ♂	74	17	18	8
Trail ♀	58	17	18	7
Camera ♂	79	20	20	13
Camera ♀	26	18	18	8
Cove ♂	86	17	17	9
MEAN	65	18	18	9
MEAN, ALL YEARS	76	19	21	10
		PAIRS		
		1975		
PF-2	144	21	22	14
		1976		
Camera	140	26	26	18
Loaf	162	26	30	16
Hump	87	22	26	9
MEAN	130	25	27	15
		1977		
Trail	92	17	18	10
Camera	99	20	20	12
MEAN	96	19	19	11
MEAN, ALL YEARS	121	22	24	13

Appendix E. Dimensions of red-tailed hawk home ranges in the BPSA during the brood-rearing and post-fledging periods, 1975-77.

Individual/ Site	Home range (km^2)	Maximum dist. from nest (km)	Maximum length of home range (km)	Maximum width of home range along the canyon (km)
		INDIVIDUALS		
		1975		
Priest ♂	27	6	9	5
		1976		
Priest ♂	20	5	5	5
Black Butte ♂	13	5	6	5
MEAN	17	5	6	5
		1977		
Halverson ♂	10	5	7	4
Halverson ♀	4	1	3	2
Cabin Draw ♂	20	6	7	4
Cabin Draw ♀	15	7	7	3
Black Butte ♂	15	4	5	5
Black Butte ♀	1	1	1	1
Cove ♂	20	8	9	9
MEAN	12	5	6	4
MEAN, ALL YEARS	15	5	6	4
		PAIRS		
		1976		
Black Butte	13	5	6	5
		1977		
Halverson	11	5	7	4
Cabin Draw	22	7	7	4
Black Butte	15	4	5	5
MEAN	16	5	6	5
MEAN, ALL YEARS	15	5	6	5

Appendix F. Prey items found at systematically sampled golden eagle nest sites, 1971-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
Mammals				
Black-tailed Jackrabbit	1,032	35.4	1,738,728	59.8
Mountain Cottontail	544	18.7	304,163	10.5
Townsend Ground Squirrel	281	9.6	53,021	1.8
Yellow-bellied Marmot	100	3.4	206,172	7.1
Pocket Gopher, Unid	65	2.2	12,500	0.4
Bushy-tailed Woodrat	21	0.7	6,355	0.2
Muskrat	15	0.5	18,339	0.6
Kangaroo Rat, Unid	10	0.3	530	+
Rabbit, Unid.	9	0.3	8,605	0.3
Desert Woodrat	9	0.3	1,275	+
Woodrat, Unid.	8	0.3	1,840	0.1
Antelope Ground Squirrel	7	0.2	615	+
Coyote	6	0.2	12,258	0.4
Meadow Mouse	6	0.2	180	+
Ord Kangaroo Rat	5	0.2	265	+
Long-tailed Weasel	4	0.1	619	+
Least Chipmunk	3	0.1	96	+
Pronghorn Antelope	2	0.1	5,400	0.2
Pygmy Rabbit	2	0.1	680	+
Ground Squirrel, Unid.	2	0.1	344	+
Mouse, Unid.	2	0.1	50	+
Mule Deer	1	+	6,300	0.2
Porcupine	1	+	5,800	0.2
Badger	1	+	2,833	0.1
Rodent, Unid.	1	+	50	+
Deer Mouse	1	+	19	+
Bat, Unid.	1	+	10	+
SUBTOTAL	2,139	73.10	2,387,047	81.9
Birds				
Ring-necked Pheasant	337	11.6	343,484	11.8
Rock Dove	83	2.8	26,464	0.9
Chukar	43	1.5	25,886	0.9
Passerine, Unid.	25	0.9	1,482	0.1
Raven	15	0.5	12,831	0.4
Black-billed Magpie	15	0.5	2,250	0.1
Mallard	9	0.3	10,572	0.4
Prairie Falcon	8	0.3	5,400	0.2
Great Horned Owl	7	0.2	10,535	0.4
Starling	7	0.2	553	+
American Coot	6	0.2	3,924	0.1

Appendix F (cont.). Prey items found at systematically sampled golden eagle nest sites, 1971-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
Birds (cont.)				
Duck, Unid.	6	0.2	2,155	0.1
American Kestrel	6	0.2	684	+
Gray Partridge	5	0.2	1,945	0.1
Barn Owl	4	0.1	2,412	0.1
California Quail	4	0.1	680	+
Western Meadowlark	4	0.1	384	+
Mourning Dove	3	0.1	402	+
Great Blue Heron	2	0.1	4,015	0.1
Red-tailed Hawk	2	0.1	2,112	0.1
Pintail	2	0.1	2,001	0.1
California Gull	2	0.1	1,538	0.1
Galliformes, Unid.	2	0.1	1,060	+
Green-Winged Teal	2	0.1	631	+
Sparrow, Unid.	2	0.1	52	+
Domestic Chicken	1	+	3,120	0.1
Ferruginous Hawk	1	+	1,056	+
American Wigeon	1	+	767	+
Shoveler	1	+	681	+
Gull, Unid	1	+	633	+
Teal, Unid.	1	+	354	+
Cinnamon Teal	1	+	354	+
Short-eared Owl	1	+	348	+
Bobwhite	1	+	137	+
Nighthawk	1	+	106	+
Sage Thrasher	1	+	28	+
Mountain Bluebird	1	+	20	+
SUBTOTAL	613	20.7	471,056	16.1
Reptiles				
Gopher Snake	64	2.2	14,764	0.5
Snake, Unid.	27	0.9	5,589	0.2
Western Rattlesnake	3	0.1	819	+
Lizard, Unid.	3	0.1	48	+
Striped Whipsnake	2	0.1	212	+
Long-nosed Snake	2	0.1	109	+
Leopard Lizard	2	0.1	49	+
Reptile, Unid.	1	+	138	+
SUBTOTAL	104	3.6	21,728	0.7

Appendix F (cont.). Prey items found at systematically sampled golden eagle nest sites, 1971-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
Fish				
Carp	39	1.3	22,654	0.8
Fish, Unid.	8	0.3	4,231	0.1
Squawfish	6	0.2	590	+
Sucker	2	0.1	240	+
Whitefish	2	0.1	160	+
SUBTOTAL	57	2.0	27,875	0.9
Invertebrates				
Beetle	2	0.1	2	+
TOTAL	2915	99.5	2,907,708	99.6

Appendix G. Prey items found at systematically sampled prairie falcon nest sites, 1974-78.

Species	No. of Individuals	Percent of Individuals	Biomass(g)	Percent Biomass
MAMMALS				
Townsend Ground Squirrel	522	53.4	95,328	59.0
Kangaroo Rat, Unid.	37	3.8	1,961	1.2
Mountain Cottontail	17	1.7	8,011	5.0
Meadow Mouse	17	1.7	508	0.3
Deer Mouse	15	1.5	285	0.2
Black-tailed Jackrabbit	14	1.4	21,855	13.5
Rabbit, Unid.	7	0.7	6,629	4.1
Mouse, Unid.	7	0.7	175	0.1
Pocket Gopher, Unid.	5	0.5	1,000	0.6
Desert Woodrat	5	0.5	750	0.5
Antelope Ground Squirrel	4	0.4	424	0.3
Woodrat, Unid.	3	0.3	690	0.4
Rodent, Unid.	2	0.2	100	0.1
Least Chipmunk	2	0.2	64	+
Grasshopper Mouse	1	0.1	33	+
Fetus, Unid.	1	0.1	20	+
Harvest Mouse	1	0.1	11	+
SUBTOTAL	660	67.3	137,844	85.3
BIRDS				
Passerine, Unid.	55	5.6	3,106	1.9
Horned Lark	37	3.8	953	0.6
Western Meadowlark	31	3.2	2,920	1.8
Rock Dove	12	1.2	3,984	2.5
Rufous-sided Towhee	7	0.7	287	0.2
House Finch	7	0.7	154	0.1
Starling	5	0.5	395	0.2
Sparrow Unid.	5	0.5	98	0.1
Ring-necked Pheasant	4	0.4	3,853	2.4
Lark Sparrow	4	0.4	112	0.1
Black-billed Magpie	3	0.3	510	0.3
Mourning Dove	3	0.3	402	0.2
Brewer's Blackbird	3	0.3	204	0.1
Red-winged Blackbird	3	0.3	144	0.1
Sage Thrasher	3	0.3	111	0.1
Sage Sparrow	3	0.3	58	+
Rock Wren	3	0.3	51	+
Chukar	2	0.2	1,204	0.7

Appendix G (cont.). Prey items found at systematically sampled prairie falcon nest sites, 1974-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
BIRDS (cont.)				
Robin	2	0.2	158	0.1
Loggerhead Shrike	2	0.2	102	0.1
Cliff Swallow	2	0.2	50	+
Water Pipit	2	0.2	38	+
American Coot	1	0.1	654	0.4
Gray Partridge	1	0.1	389	0.2
Short-eared Owl	1	0.1	348	0.2
California Quail	1	0.1	170	0.1
Nighthawk	1	0.1	106	0.1
Killdeer	1	0.1	104	0.1
Yellow-headed Blackbird	1	0.1	74	+
Blue Jay	1	0.1	74	+
American Kestrel	1	0.1	57	+
Poor-will	1	0.1	43	+
Grasshopper Sparrow	1	0.1	26	+
Swallow, Unid.	1	0.1	25	+
Yellow-breasted Chat	1	0.1	23	+
Lazuli Bunting	1	0.1	15	+
Red-breasted Nuthatch	1	0.1	11	+
SUBTOTAL	213	21.6	21,013	12.7
REPTILES				
Horned Lizard	32	3.3	654	0.4
Whiptail Lizard	23	2.4	347	0.2
Lizard, Unid.	8	0.8	128	0.1
Leopard Lizard	7	0.7	161	0.1
Snake, Unid.	4	0.4	828	0.5
Western Fence Lizard	3	0.3	51	+
Gopher Snake	2	0.2	230	0.1
Collared Lizard	2	0.2	56	+
Reptile, Unid.	1	0.1	138	0.1
SUBTOTAL	82	8.4	2,593	1.5
INVERTEBRATES				
Beetle	13	1.3	13	+
Scorpion	7	0.7	7	+
Jerusalem Cricket	3	0.3	6	+
SUBTOTAL	23	2.3	26	—
TOTAL	978	99.6	161,516	99.5

Appendix H. Prey items found at systematically sampled red-tailed hawk nest sites, 1973-78.

Species	No. of Individuals	Percent of Individuals	Biomass(g)	Percent Biomass
MAMMALS				
Townsend Ground Squirrel	566	35.7	101,527	25.1
Mountain Cottontail	148	9.3	66,269	16.4
Kangaroo Rat, Unid.	115	7.3	6,070	1.5
Black-tailed Jackrabbit	93	5.9	108,062	26.8
Pocket Gopher, Unid.	53	3.3	9,700	2.4
Meadow Mouse	23	1.5	690	0.2
Rabbit, Unid.	22	1.4	18,725	4.6
Deer Mouse	22	1.4	409	0.1
Woodrat, Unid.	15	0.9	3,370	0.8
Yellow-bellied Marmot	10	0.6	16,485	4.1
Harvest Mouse	8	0.5	88	+
Desert Woodrat	6	0.4	825	0.2
Mouse, Unid.	5	0.3	125	+
Ord Kangaroo Rat	4	0.3	212	0.1
Long-tailed Weasel	3	0.2	534	0.1
Antelope Ground Squirrel	3	0.2	318	0.1
Least Chipmunk	3	0.2	96	0.0
Muskrat	2	0.1	2,236	0.6
Rodent, Unid.	2	0.1	100	+
Domestic Cat	1	0.1	1,800	0.4
Bushy-tailed Woodrat	1	0.1	155	+
House Mouse	1	0.1	17	+
Great Basin Pocket Mouse	1	0.1	15	+
Shrew, Unid.	1	0.1	6	+
SUBTOTAL	1,108	70.1	337,834	83.5
BIRDS				
Passerine, Unid.	39	2.5	2,156	0.5
Western Meadowlark	8	0.5	768	0.2
Rock Dove	7	0.4	2,324	0.6
Horned Lark	7	0.4	182	+
Cliff Swallow	6	0.4	150	+
Black-billed Magpie	5	0.3	841	0.2
Sparrow, Unid.	5	0.3	130	+
Ring-necked Pheasant	3	0.2	3,414	0.8
Chukar	3	0.2	1,806	0.4
Starling	3	0.2	237	0.1
Brewer's Blackbird	3	0.2	204	0.1
Yellow-headed Blackbird	3	0.2	203	0.1
Red-winged Blackbird	3	0.2	144	+

Appendix H (cont.). Prey items found at systematically sampled red-tailed hawk nest sites, 1973-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
BIRDS (cont.)				
Mourning Dove	2	0.1	265	0.1
Nighthawk	2	0.1	212	0.1
Duck, Unid.	2	0.1	200	+
Say's Phoebe	2	0.1	56	+
Mallard	1	0.1	1,185	0.3
American Wigeon	1	0.1	772	0.2
American Coot	1	0.1	654	0.2
Barn Owl	1	0.1	603	0.1
Galliformes, Unid.	1	0.1	400	0.1
Blue-winged Teal	1	0.1	323	0.1
California Quail	1	0.1	170	+
American Kestrel	1	0.1	114	+
Robin	1	0.1	79	+
Rail Unid.	1	0.1	70	+
Poor-will	1	0.1	43	+
Sage Sparrow	1	0.1	24	+
SUBTOTAL	115	7.6	17,727	4.2
REPTILES				
Gopher Snake	150	9.5	30,492	7.6
Snake, Unid.	48	3.0	8,620	2.1
Whiptail Lizard	22	1.4	337	0.1
Striped Whipsnake	20	1.3	2,150	0.5
Lizard, Unid.	19	1.2	304	0.1
Ground Snake	13	0.8	104	+
Western Rattlesnake	11	0.7	4,097	1.0
Western Fence Lizard	9	0.6	153	+
Racer	5	0.3	376	0.1
Leopard Lizard	5	0.3	124	+
Reptile, Unid.	4	0.3	552	0.1
Night Snake	4	0.3	56	+
Side-blotched Lizard	4	0.3	16	+
Long-nosed Snake	3	0.2	164	+
Horned Lizard	2	0.1	42	+
SUBTOTAL	319	20.3	47,587	11.6

Appendix H (cont.). Prey items found at systematically sampled red-tailed hawk nest sites, 1973-78.

Species	No. of Individuals	Percent of Individuals	Biomass (g)	Percent Biomass
AMPHIBIANS				
Leopard Frog	1	0.1	38	+
Fish				
Fish, Unid.	1	0.1	583	0.1
INVERTEBRATES				
Beetle	33	2.1	33	+
Scorpion	6	0.4	6	+
Grasshopper	2	0.1	2	+
Spider	1	0.1	1	+
SUBTOTAL	42	2.7	42	
TOTAL	1,586	100.9	403,811	99.4

PHOTO CREDITS

Page	Description	Photographer
Frontispiece	Five-week old prairie falcon nestling	Lowell Diller
1	Young golden eagle in nest	Michael N. Kochert
4	Snake River Canyon near Swan Falls	Michael N. Kochert
6	Native shrub community in BPSA	Albert R. Bammann
7	Typical agricultural development	Merv Coleman
9	Landsat photo of BPSA and Comparison Area	NASA
23	Black-tailed jackrabbit	Thomas E. Kucera
48	Adult golden eagle with young	Michael W. Collopy
78	Young red-tailed hawks with ground squirrel prey	Michael N. Kochert
89	11-week old golden eaglet	Michael N. Kochert

* GPO 799 - 196 1981